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OF THE

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INCLUDING

ORIGINAL COMMUNICATIONS ON TELEGRAPHY AND ELECTRICAL SCIENCE.

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OF THE

Institution of Electrical Engineers.

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The Two Hundred and Eighty-second Ordinary General Meeting of the Institution was held at the Institution of Civil Engineers, 25, Great George Street, Westminster, on Thursday evening, January 16th, 1896—Mr. R. E. CROMPTON, late President, in the Chair.

The minutes of the Annual General Meeting of December 12th were read and approved.

The names of new candidates for election into the Institution were announced and ordered to be suspended.

The following transfers were announced as having been approved by the Council:—

From the class of Associates to that of Members—

Francis E. Gripper.
Haydn T. Harrison.
William Kingsland.
Gerald W. Partridge.
Robert William Paul.
John Francis C. Snell.

From the class of Students to that of Associates—

H. S. Davidson.
Louis Henry Euler.
Walter Eynon.
Dennis H. Felce.
David J. Gadsby.
Julian Halford.
Granville C. Knight.
Hugh Innes Rogers.
Charles Henry Stobart.
Thomas Parry O. Yale.

Mr. W. Clark and Mr. H. E. Mitchell were appointed scrutineers of the ballot.

The CHAIRMAN: I have now, as my last official duty, the very pleasing task of announcing and presenting the premiums for papers read during the past year. I have to present the "Institution Premium" to Mr. Mark Robinson, Member, for his paper on "The Recent Development of the Single-Acting "High-Speed Engine for Central Station Work." I have to congratulate him upon his splendid paper. The "Paris Electrical "Exhibition Premium" goes to Professor Ewing for his paper on "The Magnetic Test for Measuring Hysteresis in Sheet Iron," and I have much pleasure in presenting to him the recognition of our appreciation of his most useful invention. The "Fahie "Premium" is awarded to Mr. J. E. Kingsbury for his paper on "The Origin and Development of the Telegraph Switch-Board." Unfortunately, Mr. Kingsbury has been suddenly called away this evening. The "Students' Premium" goes to Mr. Eborall for his paper on "Single-Phase Alternate-Current Motors." He is abroad, so the books he has selected will be forwarded to him. I have next the pleasure of handing to Mr. Joseph Petavel, of University College, a cheque for £45, representing the Salomons Scholarship awarded to him. Mr. Percy Rhodes Cobb, of King's College, who gained the other Salomons Scholarship, of equal value, is just now on the Continent, and his cheque will be duly handed to him on his return.

The CHAIRMAN: My last duty is now reached, viz., to vacate the chair in favour of a better man. I do not think the choice of the Institution could have fallen on one more worthy than Dr. Hopkinson, to whom we all owe so much. By his scientific work, by his practical contributions to our scientific knowledge of the dynamo, and by his careful study of the properties of the materials that we use in the construction of electrical apparatus, he has done more almost than any known Englishman—or, I may say, any man in any country—to forward the great cause of electrical engineering. I can only say that I feel very proud to be succeeded by such a great man.

Dr. Hopkinson then took the chair.

General WEBBER: It is my unexpected, but warmly appreciated, duty to ask the Institution, and all our guests present here this evening, to testify, with acclamation—"That the cordial "thanks of the Institution are due to Mr. Crompton for the energy "and ability he has displayed in performing the duties of President "during the past year." Of his energy and of his efficiency those who have attended our meetings are fully aware. But of his efficiency in your Council Chamber, of his efficiency as chairman of your committees, you can have but little knowledge, except through your previous acquaintance with the energy, zeal, and ability which he has given to all the work that he has undertaken during the many years that you have had the honour and pleasure of knowing him, both as a friend and a fellow-engineer. To me, this year has been quite a red-letter year, because, as our chairman, his activity, his constant attendance, and his intimate acquaintance with detail, have brought about results which, I am glad to say, will last, I think, through the history of our Institution. As chairman of one committee in particular—I am not selecting it, it merely comes to my mind at the moment—the committee for the revision of the Fire Risk Rules—he showed a power of leadership, of direction, and of guidance, which we do not often see exercised by chairmen of committees. I will not occupy your time further, but leave somebody else to second this resolution which I propose for your cordial reception.

Mr. DANE SINCLAIR: I have very much pleasure indeed in seconding the resolution so eloquently moved by General Webber. In the presence of our late President it is useless to say any more than has already been said; his energy and ability speak for themselves. We have only to tender our thanks to him in a very hearty manner.

The resolution was put, and carried unanimously.

Mr. R. E. CROMPTON: Gentlemen,—I can say little, except that, while filling the honourable position of your President, I have tried to do what I could, and that I am afraid that has not been as much as I could have wished. If I had been longer at it, perhaps I should have done better; the fact is, one is just beginning to learn the work at the very time one leaves it. I

only hope I may have been of some little service. I am sure those who follow me will do the work much better.

The PRESIDENT: Gentlemen,—Before proceeding with my Presidential Address, I wish to say a few words on another subject. Recent events have made unpleasant revelations to many of us. They have shown us that there are, among other peoples, certain persons who would regard with satisfaction any misfortune which might befall this country, and that any little matter of dispute, or perhaps any error committed by a mere handful of our countrymen, may be magnified by those persons who do not like us, so as to involve us in a quarrel with peoples whom we have always been in the habit of regarding as our friends. Such a quarrel might very easily cause danger to our vital interests. To provide against such a danger is not a "jingo" move. It threatens no one. It simply means that we will not allow the consequences which might follow, even from the errors or the follies of our countrymen, to cause terrible mischief at home. Continental nations generally aim at obtaining safety by compulsory military service, with ample time for training, from every able-bodied citizen. We hope to obtain it without forcing service upon anyone. Surely, if it is the duty of each of us to consider what he personally can contribute to the safety of his country, it is the duty of any great Institution such as this to ascertain whether any action it can take in its corporate capacity can be made to help towards attaining the same end! Now, gentlemen, you possess aptitudes which might be of great use, particularly for purposes of defence, in the unhappy eventuality of war. The number of past and present Royal Engineers on our roll shows the interest which military men take in the various branches of our profession. If you think of the use of electricity for military telegraphs, search lights, the training of guns, submarine mines, and so on, I think you will agree that, properly organised, our technical knowledge might be very useful indeed. It cannot be doubted that many of you would be glad to give your services, as far as they could be made useful. The question is, How can that be done? and, What steps can be taken to do it? I know certainly for a fact that anything we

could do effectively would be welcomed heartily by the highest authorities in the Army. Of course, too, I have privately consulted some of our members. I wrote some days ago, amongst others, to Lord Kelvin, as one of the oldest, and certainly the most distinguished, amongst us, asking what he thought of the idea of utilising the qualifications of the electrical engineers for the purposes of national defence. He writes: "I cordially "approve of your movement to promote the utilisation of the "patriotism and abilities of electrical engineers for national "defence, and I shall be glad to do all I can to help you in "respect to it. I hope and expect valuable results for our "country." Others, who are unable to be here, agree that such a movement would be eminently useful, and at the present moment would be likely to be successful. The Council have accordingly this evening passed the following resolution:—"That steps should be taken to render available, for purposes "of national defence, the technical skill of electrical engineers; "and that a committee be appointed, with instructions to take "such measures as it thinks fit to attain that end." The following gentlemen have been nominated as members of that committee:—The President, Sir Frederick Abel, Mr. Crompton, Mr. H. Edmunds, Mr. R. S. Erskine, Mr. A. E. Mavor, and Major-General Webber, with power to add to their number. Probably this committee will, first of all, ascertain what members of the Institution are willing to serve, and what time they can give to training. It will also ascertain what places want filling in existing corps, and endeavour to put the right men in the way of filling them. If we have more men than there are vacancies to be filled, new corps might be formed of such men. These are matters of detail which will have to be considered by this committee. Gentlemen, if each of us will do his duty according to his opportunities, we shall succeed in rendering valuable services to our country.

The President's remarks, and his announcement of the steps taken by the Council, were received by the meeting with the utmost enthusiasm.

Mr. R. S. Erskine: Gentlemen,—I am sure a great number of members of this Institution must be in sympathy with Dr. Hopkinson. I am sure many of us can, and will, work, in one way or another, in the manner suggested by him. I think some expression should be given this evening to support the President in the movement he has started.

The meeting again testified its warm approval of the movement.

The President: I think I should ascertain whether it is your desire that anything further should now be said on this subject. Those who think that we should delay our other proceedings a little, and hear what any member may desire to say on the matter, will kindly hold up their hands.

A show of hands having been taken,

The President: Well, gentlemen, I think that, although you have so warmly evinced your approval of the steps taken by the Council, there is evidently not any strong feeling that more need be said on this subject at the present moment, and, if you will allow me, therefore I will proceed with my Address.

INAUGURAL ADDRESS.

By Dr. John Hopkinson, M.A., F.R.S., President.

When it was suddenly proposed to me that I should a second time be your President, I felt considerable reluctance to accept the duty. This reluctance arose from two causes. Of the first I am ashamed—pure laziness—and of it the less I say the better. The second was a *bonâ fide* doubt as to whether I was specially suitable for the post. But it soon struck me that that was a matter for which those who proposed me were responsible, and not I who accepted, but had not sought the office. But, if I felt a temporary reluctance, do not suppose that I for a moment failed to appreciate the honour which had been done me. To be called by his fellow professional men to fill the chair which has been occupied by men of such distinction as Kelvin, Siemens, Abel, Crookes, not to mention others, is an honour of which anyone

may confess himself proud. After once having occupied this chair, to be called to it a second time is a greater honour, for it shows that one's efforts, however imperfect, have been generously appreciated by those for whom they were made. I thank you for the honour, and assure you I will do my best to verify, if I can, the judgment of those who proposed and you who elected me, rather than my own misgivings.

The century which is now just drawing to a close has been a time remarkable above all other times for the extraordinary development of our knowledge of the physical sciences, and in particular of experimental physics and chemistry, and for the extent of the practical application of this knowledge to useful purposes. The century has seen the discovery of the mechanical nature of heat, of the spectroscope, and of the whole of the science of organic chemistry; it has seen the enormous development of the application of the steam engine, the construction of our railway system, and the supersession of sailing vessels by steamboats. But perhaps the most remarkable illustration of this development is to be found in the science, and its application, with which this Institution has to deal. Consider what was known of the sciences of electricity and magnetism at the end of the last century. The two sciences were then quite unconnected. In magnetism the properties of permanent magnets were known—that is to say, it was known that steel needles could be rendered magnetic by rubbing with a loadstone, and that when so rendered magnetic they would tend to remain in that condition; it was known that, if a magnet were broken in parts, each part would exhibit North and South poles like the magnet from which it was broken; it was also known that the earth exhibited properties of magnetism, inasmuch as a magnetic needle free to move would point, on the whole, to the North; broadly speaking, what we know to-day about permanent magnets was known, and that was about all. The practical applications were limited to the use of a magnetic needle in the mariner's compass. The knowledge of electricity was confined to what is now known as electrostatics. That certain bodies when rubbed exhibited peculiar properties, attracting and repelling each other, had long been observed; and

the facts expressed by the hypothesis of positive and negative electricity were known—namely, that two pieces of amber which had been rubbed repelled each other, two pieces of glass which had been rubbed repelled each other, but a piece of rubbed glass and a piece of rubbed amber attracted each other. In a general way the properties of conductors, as distinguished from insulators, were also known in their relation to charges of frictional electricity. Cavendish had made elaborate investigations into the capacity of condensers, the condensers being usually of glass, and being charged by the old-fashioned frictional means. Franklin had proved the identity of the cause of lightning with the cause of the sparks produced by frictional electricity. Just one hundred years ago Galvani had made his celebrated experiments showing that the muscles of the limb of a frog were disturbed by contact with a piece of copper and a piece of zinc which touched each other; and that was the only fact which up to that time had ever been observed in the enormous group of facts which now constitute our knowledge of the production of electricity by chemical action. Shortly stated, that was the extent of our theoretical and experimental knowledge of electricity. The practical applications of this knowledge were almost *nil*. I can recall nothing excepting the provision of lightning conductors as a protection to buildings.

It is worth insisting that the additions to our knowledge of the properties of permanent magnets and of frictional electricity during the century have not been of great importance, and the practical applications of these limited branches of knowledge have been few. If one is asked what uses can be made of our knowledge of frictional electricity apart from the phenomena of currents, it is hard to name anything of importance. In like manner, in regard to our knowledge of permanent magnets, it may almost be said that the advances in practical applications have been confined to improvements in the use of the mariner's compass, which, most important although they are, have had comparatively little share in the changes in our conditions which the last hundred years have witnessed. Almost everything in the way of practical applications of electrical science has been the outcome of subsequent discoveries—the

voltaic cell, discovered by Volta in the year 1800; Davy's discoveries in electrolysis; Oersted's discovery of the action of currents upon magnets; Ampère's discoveries of the mechanical action of currents upon currents; and Faraday's discoveries in electro-magnetism; not to mention the names of eminent men still living. Now the remarkable thing is that none of these phenomena had ever been witnessed by mortal man. It was not that they were constantly occurring around us, and that the explanation had not been seen; it is the fact that the phenomena had never been experienced. It would seem that the phenomena of electric currents as Volta discovered them do not occur in nature on any substantial scale. Electro-magnets may be regarded as purely a creation of the human mind; so far as we know at present, no example of an electro-magnet is found in the natural world. The great currents produced by the action of electro-magnets have, so far as we know, no counterpart in nature—not only no counterpart in degree, but none in kind. In this respect our science differs much from many others. In mechanics and in heat we may find the phenomenon of which we make use occurring without our aid on an enormously greater scale than we are accustomed to use; changes are constantly occurring around us, and it is conceivable that we might have obtained much of our present knowledge by the aid of observation without experiments. But it is not so with electricity and magnetism. We should be puzzled even now to adequately illustrate the facts we know by observation alone without experiment.

Let us consider for a moment the practical applications which have been made of electrical knowledge during the last 60 years. The first, of course, is the telegraph. What are the scientific facts which have been used in the development of telegraphy? The currents are generated either by chemical means or electro-magnetic means. The receiving instruments either depend for their action on the action of currents upon magnets, or, in a limited number of cases, on electro-chemical decomposition. We might put it broadly thus—that, with the exception of the distinction between conductors and

non-conductors and certain properties of condensers, the telegraph could do without anything that was known up to the end of the last century, and that it wholly depends upon more recent discoveries. Much the same may be said with regard to the more recent applications: the electric light, electric transmission of power, and the rapidly growing department of electro-chemistry may all be said to be quite independent of any facts which were known before the year 1800, and entirely based upon discoveries made since. Suppose it were a fact that electricity could not be produced by friction, that we knew nothing concerning the attraction which oppositely electrified bodies have for each other, that permanent magnets did not exist—or, in other words, that iron had no hysteresis—would it make any material difference, so far as we know, in the practical applications of electrical science to telegraphy, telephony, electric light, electric transmission of power, or electro-chemistry? The permanent magnets, which are practically used only in instruments, would be at once replaced by electro-magnets, and the apparatus would work just as it does now.

Enough has been said, I think, to show that the knowledge of electricity and magnetism which was possessed by men at the end of the last century, intensely interesting though it was, has not been the parent of the great applications of later days; that the knowledge of the last century has not grown in any great degree upon the lines which existed at its commencement, but that our advances in science, as in practice, were the result of the discoveries which were made since the beginning of the present century.

It has been a frequent practice with presidents of societies devoted to promoting some department of science, theoretic or applied, to deal with the history of the science in their presidential addresses,—to show how one idea has led up to another, and how marked have been the advances made. This evening I propose to adopt a different course. What I wish to consider is, how would the theory of electricity have been arranged if the order of discovery of the facts of the science had been other than it has been? Here I owe you some words of

apology. You are a practical body more immediately interested in the application of science to the service of man than in the promotion of abstract knowledge. The justification I would offer for my subject is that the science of electricity, whether viewed from the practical or theoretical side, is in a state of extraordinarily rapid advance. The rules of practice of yesterday are of little use to-day, hence more discussion is needed, more publication is needed, than in departments which are in a more stable state. Furthermore, there is no department of applied science in which the connection with theory is so close and intimate. The practical electrical engineer reads eagerly the results of those who, careless whether their work finds application or not, labour to advance knowledge; he attacks these results whether they be expressed in the ordinary speech of men or in mathematical symbols. On the other hand, much of our knowledge of electricity, viewed from the scientific side, has come from those who are concerned with practical application. Nowhere else do we find a closer interdependence of pure science and practice. In what I have to say there will be much that is trite and obvious to the merest tyro in electricity. What I wish to do is to show how the facts of electrostatics can be explained by the facts of current-electricity without hypothesis; and it is necessary to rehearse elementary principles. In a complicated subject like electricity, in which the appeals to our senses are indirect, there are open to us many ways of arranging our ideas, any one of which will give us a consistent account of that which we observe. We may take as our fundamental basis one or other of various groups of facts, and deduce others therefrom. The actual arrangement of ideas on the subject depends in a measure upon the accident of the historical order of discovery. Thus, the fact that actions at a distance between electrified bodies were known many years before the phenomena of current-electricity and electro-magnetism is the reason why that part of the science which treats of such actions is to-day treated first and made the basis of the rest. The time has, I think, come when we may with advantage reconsider our position, and see whether or not our ideas may be

more conveniently arranged. The arrangement which is most convenient may no doubt depend upon the phenomena which occupy the most prominent place in the practical use we wish to make of the science. Those facts are best treated as fundamental which are most frequently used, provided they are sufficiently simple. To the practical electrician, are the facts of current-electricity, or of the attractions and repulsions of electrified bodies, more familiar? Surely the transference of energy by current is the agent by which almost every operation he purposes is effected, whilst the phenomena of electrostatics touch him only at points in the theory of electrometers and so forth. I propose, then, this evening to sketch out very briefly, *ab initio*, how we may base the science of electrostatics upon the theory of current-electricity taken as fundamental. We might, if we pleased, drop the word "current" altogether and substitute another. It seems hardly worth while, but I shall ask you to bear in mind that, if used to-night, it does not connote the idea of anything flowing along the conductor. It is a name for a directed magnitude, and nothing more. I shall have occasion to refer to some elementary experiments, but you will bear with me, I trust, for we are concerned with arranging the subject on as small a basis of facts as is consistent with rigid deduction. Please, then, to banish from your minds all theory on the subject, and let us imagine that the facts of current-electricity are first discovered, and that it is only when these are well developed that electrostatic attractions and repulsions are found out.

In a vessel of dilute sulphuric acid is placed a piece of pure zinc, or of zinc carefully amalgamated, and also a piece of copper, platinum, silver, or carbon, the two plates not being in contact with each other. It is observed that no change takes place; the acid does not attack either plate. The two plates are now touched with the two ends of a wire of copper or other metal; immediately the zinc begins to dissolve in the sulphuric acid, and gas—which, if collected, proves to be hydrogen—is found on the copper or platinum plate. If the plates are large and near together, and the wire is not too long or thick, it becomes very sensibly heated. On separating the wire from

either plate, the chemical reaction and the heating of the wire cease. When the wire touches both plates there is then development of chemical energy in the vessel of acid; but a part of this energy appears as heat, not where it is developed, but in the wire connecting the plates. Whether this energy goes across the space of air between the zinc plate and the wire, or whether it goes along the wire, we do not know; but that the two plates should be rendered continuous with each other by a wire or some equivalent is a condition precedent to the chemical reaction and to the heating of the wire.

Let two such vessels of dilute acid, with plates of zinc and copper, be provided, and let the copper in one vessel be connected metallically to the zinc in the other: nothing happens until the copper in the second vessel is connected to the zinc of the first; then both zincs are dissolved, hydrogen is liberated on both copper plates, and the connecting wires are more or less heated.

Again, varying the experiment, let the coppers in the two vessels be connected together and the zincs be connected together: no reaction or heating occurs.

The combination of a piece of zinc and a piece of copper dipping separately into a vessel of dilute acid is called a "galvanic cell," or element; a series of elements connected together copper to zinc is called a "galvanic battery." Galvanic elements and batteries take a multitude of forms: the zinc may be replaced by another metal—for example, cadmium—and the copper by platinum; many other liquids than dilute sulphuric acid may be used; but all galvanic batteries have this in common—to cause them to work, the chain or circuit must be completed by a wire touching the zinc at one end of the series and the copper at the other, and then chemical reactions occur in the cells, and heat is liberated in the metal connections. The zinc and copper plates, or their equivalents, at the ends of a galvanic battery are called "poles."

Let two plates of platinum dip into dilute sulphuric acid; connect one plate by means of a wire to the zinc pole of a battery, the other plate to the copper pole. So soon as the connections are made, chemical reactions occur in the cells of the battery, the connecting wires are more or less heated, and, further, a reaction

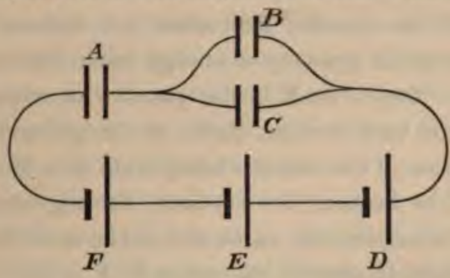
occurs in the vessel in which the platinum plates dip, the water is decomposed, gases are liberated on the two plates; if these are collected, it is found that the gas from the plate connected to the zinc pole is hydrogen, that from the plate connected to the copper is oxygen. The effects cease on detaching either wire from the platinum plate or the pole of the battery, or otherwise interrupting the continuity of the circuit. In this experiment is seen a chemical reaction liberating energy in the cells of the battery, and another chemical reaction absorbing energy in the vessel containing the platinum plates; how the energy passes from one vessel to the other we do not know.

The experiment may be varied. Let two plates of zinc or other metal dip into a solution of salt of zinc or other metal, and let the plates be connected to the poles of a galvanic battery for a time. If the plates be weighed before and after the operation, it is found that the plate which was connected to the zinc pole has gained in weight, and that the plate which has been connected to the copper has lost an equal amount. By weighing such plates, and noting the time the experiment was allowed to continue, it is practicable to examine quantitatively the phenomena of a galvanic circuit. Such pair of plates and solution of salt is called a "voltameter."

Suppose now a series of voltameters, having in each the same metal, are connected together in a chain, a plate of one to a plate of the next, and the two ends of the chain connected to the two poles of a battery, it is found that, no matter what be the size and form of the voltameters, their position, or the arrangement of the connecting wires, there is the same gain and loss of weight of the plates in all the voltameters; it is further found that, if the zincs of the cells of the battery are weighed before and after the experiment, and if the metal used in the voltameter be zinc, the quantity of zinc dissolved is the same in all the cells, and is the same as that transferred in each voltameter. The rate of dissolution and deposit is the same in the several voltameters and cells. In a closed galvanic circuit we have, then, a measurable something the same for all cross-sections of the circuit, measurable by the quantity of zinc or other selected metal which is transferred from one plate to the other of a voltameter in a unit of time. This

something has direction as well as magnitude, and as the magnitude may be represented in terms of any unit chosen by a numerical quantity C, so the direction may be represented by the sign + or −. It is arbitrarily chosen to take as + the direction from the plate which loses weight to that which gains weight through the liquid in the voltameter. The quantity C taken, with its sign, is called the galvanic or electric current round the circuit, but it must not be supposed that it is known that there is anything flowing round the circuit.

Suppose that, instead of a simple galvanic circuit, the circuit divides or branches as indicated in the sketch, in which A, B, C, are voltameters, F E D the battery. It is found that the quantity



of zinc moved in B, together with the quantity of zinc moved in C, is equal to the quantity moved in A. This gives us the idea of current in the branch B or C, and we may say that the current in A is the algebraic sum of the currents in B and C.

Not all bodies are competent to complete a galvanic circuit. Thus, if the copper wires which serve to connect the poles of the cells of the batteries and the voltameter are any of them replaced by thread, the phenomena of galvanism do not occur; if one of the wires be severed and a piece of paraffined paper interposed, the phenomena do not occur.

Thus we have a distinction of substances into those which are capable of forming continuously part of a galvanic circuit and those which are not; the former are called "conductors," the latter "non-conductors." The distinction will be found to be really one of degree.

Consider a wire forming part of the galvanic circuit: after a short time no change occurs in the wire; it is heated by the

current, and it loses heat by heat conduction, convection, or radiation. It is possible by the methods of calorimetry to measure the total quantity of energy leaving the wire as heat by these agencies; it must be equal to the quantity of energy brought into the wire by galvanic agency.

Again, consider the battery itself. A certain chemical reaction is going on; zinc is being oxidised, and other reactions are occurring. Of the net amount of energy liberated per second by these, some goes to heat the battery, but some also appears in parts of the circuit external to the battery—that is, leaves the battery by galvanic agency. Thus a galvanic current is an instrument which takes energy from certain parts of the circuit and takes it into other parts of the circuit; and when the current is steady the algebraic sum of the quantity of energy taken into all parts of the circuit is *nil*. Denote by E C the quantity of energy per unit of time taken into any section, A, B, of the galvanic circuit, the positive direction of the current being from A to B. If the whole of the circuit be broken into sections, the algebraic sum of the values of E C is *nil*, but the value of C is the same for all sections; hence the algebraic sum of the values of E is *nil*. Let there be any quantity, V_a, referred to each point of the circuit, such that $V_a - V_b = E$, the condition that the sums of the values of E shall be *nil* is fulfilled. E is therefore properly described as the difference of two quantities, one peculiar to A, the other to B; it is called the difference of potential between A and B, and V_a is called the potential at A, though it is only with differences of potential that we are concerned.

Suppose now the circuit divides at A into two or more branches, joining again at B, by our definition the difference of potential between A and B is the sum of the energies taken per unit of time into the conductors A, B, divided by the sum of the currents in the conductors A, B. We have now to show that the energy taken into each of the conductors A, B, is equal to the difference of potential between A and B multiplied by the current in that conductor. This is by no means obvious, but depends on an assumption of an experimental truth, viz., that in a given conductor the energy taken into it by the current is a function of the

current only, and is independent of other conditions external to the conductor. Granted this, it easily follows that, if two or more conductors be joined at A and B, the potential difference between A and B deduced from each will be the same.

As we have defined difference of potential by means of work done in a conductor when a given current exists in it, the laws of resistance must have the same basis. In the case of a homogeneous metallic conductor under given constant physical conditions of temperature, stress, and magnetic field carrying a constant galvanic current C, Joule found that the heat liberated per unit of time varies as the square of $C = R C^2$ when R is a constant relative to C for the conductor. Whence follows that $E = R C$ R is called the electrical resistance of the conductor. For metallic conductors R is constant, but the constant R does not exist for all conductors; for the electric arc, for example, the heat generated varies more nearly as C than as C^2, and therefore E is more nearly constant than varying as C.

We have now gained two fundamental ideas—that of galvanic current, and difference of potential. In terms of what units are we to measure them? We have only one unit to choose, because E C must be expressed in terms of our mechanical unit of power. If a unit were to be fixed at this stage, it would be natural to define either a unit of current or of resistance the ratio of $\frac{E}{C}$; for example, we might say the unit of current shall be that current whereby a unit weight of distilled water is decomposed per second; or we might say, let the resistance of a piece of wire of defined shape and material at a definite temperature be the unit of resistance. The units in general use have an electromagnetic basis, but be it observed that all rational systems must be such that E C is expressed in some ordinary mechanical units.

We have supposed that galvanic effects are measured by chemical change, and that the rate of galvanic effect—or, as it is generally called, the electric current—is measured by the rate of chemical change. From a theoretical point of view it would be possible to thus measure electric currents; but for practical

purposes other means are adopted—electrometers, galvanometers, electro-dynamometers, and the like. With a description of such instruments and their methods of use I have not the time to concern myself this evening. We must assume that we have the means of measuring C, the galvanic or electric current so called, at any instant, and E, the difference of potential, whether these be great or small, and with any desired accuracy.

We should now be in a position to give a detailed account of galvanic batteries and of electrolysis, and the theory of the distribution of currents in systems of conductors of any form, and we are in a position to place the theory of thermo-electricity upon a thermo-dynamic basis without the introduction of any fresh idea. These, however, I leave on one side, and hasten to consider how the phenomena of electrostatics can be based upon what we have been discussing. There is a broad group of facts very familiar to the practical electrician engaged in laying telegraphic cables of which I have as yet given no account: I refer to the phenomena of capacity. Let us examine a little more closely the statement that I made that if a slip of paraffined paper were interposed between the two parts of a conductor no electrical action would occur. Suppose that, instead of paraffined paper interposed between the ends of a wire, we have a very large number of sheets of tinfoil separated from each other by paraffined paper in such wise that we have a great area of tinfoil connected together, and separated from another great area of tinfoil by nothing more than the paraffined paper. If now these two areas of tinfoil are suddenly connected to the poles of a galvanic battery, we find that it is by no means true that no galvanic effect will ensue; we find that a galvanic current exists, but that, whilst it begins with a large quantity, this quantity goes on diminishing until, barring the slight imperfection of insulation of the paraffined paper, it becomes *nil*. We find, then, that it is not true to state that paraffined paper cannot form a part of a galvanic circuit; it can form a part of a galvanic circuit, but it does so under completely different laws to the metallic conductor. With the metallic conductor the difference of potential at its two ends depends only on

the current which then exists in that conductor, and not at all upon the currents which have previously existed; with paraffined paper, on the other hand, the difference of potential between the sheets of tinfoil depends not at all upon the then current, but entirely upon the currents which have existed since its two coatings were connected together, and the times for which they have existed. A galvanic current may be measured by the rate of electrolysis; being measured by a rate, its time integral will have a perfectly definite meaning, and will be measured by the total quantity of substance which would be decomposed in a voltameter in the circuit. We find that the difference of potential between the two coatings of the paraffin condenser is proportional to the time integral of the current since the time at which the coatings were connected together last. The constant ratio of this time integral of current to the difference of potential is called the "capacity" of the condenser. Suppose now that the condenser has been connected to a galvanic battery and the time integral of the current has been measured; let now the coatings of the condenser be disconnected from the battery and be connected together through any instrument for measuring the time integral of current: if this is accomplished with sufficient rapidity for loss by imperfect insulation to be negligible, we find that the time integral in the second case is equal and opposite to that which it was in the first. Here, again, is a difference from conduction in the ordinary sense. If a conductor in which a current has existed be disconnected from the source of current and be connected to any measuring instrument, no return current will be observed. Here, then, we have a new order of facts presented in an extreme case, but, in fact, applicable to all kinds of insulators. Suppose we diminish the area of surface of the paraffined paper, we diminish *pro rata* the capacity of the condenser; but even when the paraffined paper is merely interposed between the ends of two copper wires it still will be a condenser having a definite capacity. There is no need to use paraffined paper to form a condenser. Two metallic plates may be insulated and placed parallel to each other: if they be connected one to one pole of a battery, the other to the other, a current will exist for a finite time; if they are now disconnected

from the battery and connected to each other through a suitable instrument for measuring the time integral of current, a return current exists for a finite time. Consider now a condenser consisting of two parallel plates of very large area placed near to each other: its capacity varies as the area of the plates, and it also varies inversely as the distance between them—laws precisely analogous to those of conductors. It also, as might be expected, depends upon the material interposed between the two plates. Since the capacity of the condenser varies as the area, and inversely as the distance, whatever be the substance between the plates, there is a constant for every substance analogous to the specific conductivity of the material; this constant is called the "specific inductive capacity" of the material.

That the magnetic effects of the transient galvanic currents in insulators are the same as of corresponding currents in conductors, is a fundamental law at the basis of Maxwell's theory of electro-magnetism; it was, I believe, first definitely propounded by Maxwell, and it is one over which some of the most eminent minds have since contended. You will notice how, if the subject be arranged in the unhistorical, but not unnatural, way I have adopted this evening, this law drops so easily into its place, that its assumption would be almost unnoticed. Why should we assume that the magnetic effects of electric currents in insulators and in conductors are different? By far the most natural assumption is that they are the same.

Maxwell's electro-magnetic theory of light—one of the great generalisations of the century—is directly based upon this law. What is this theory? It is simple enough in its character, broadly stated. Suppose you have an electrical disturbance, a transient galvanic current, in any dielectric, this disturbance—assuming the magnetic effects of currents in dielectrics to be the same as in conductors—will be propagated as a wave in directions perpendicular to the direction of the currents. The velocity of the wave can be calculated from purely electrical experimental knowledge; it is 3×10^{10}, if the dielectric be a vacuum. The velocity of light is 3×10^{10}. We know nothing of what light is; we do know that it is a wave, and that the disturbance

is perpendicular to the direction of transmission of the light; but what is the ultimate nature of that disturbance we have no idea from the standpoint of the science of light. Is it not infinitely probable that the waves of light are none other than the electrical waves which we know must exist, and must be propagated with the observed velocity of light? And, mark, this theory demands no ether; it merely identifies the phenomenon of light with known phenomena of electricity and magnetism; it demands no knowledge of the fundamental nature of these phenomena, it demands only a knowledge of their laws. Surely Maxwell's generalisation is similar both in kind and in magnitude with the discovery of universal gravitation. Newton showed that the force which caused any body—an apple, if you like—to fall on our earth was the same as the force which kept the planets in their courses. He gave no theory of how that force was transmitted, nor of what, in its inmost nature, it was. He merely identified the two forces as one. So now Maxwell's theory may be shorn of all reference to an ether; it identifies as one the forces whereby light is transmitted and the forces with which we are familiar in our dynamo machines, and shows that they are measurably the same. It does not pretend to say what electricity and magnetism are, or what, if any, is the medium whereby the disturbances on which both depend are transmitted. Whether the postulate of an all-pervading ether be, or be not, a metaphysical necessity, surely it is well for the practical man and the physicist to leave the question to the metaphysician. My point, however, is that the hypothesis of two electric fluids and the ethereal theory of light have rather delayed than accelerated the acceptance of a great generalisation. Let us now return to elementary matters.

I have just stated that the capacity of two large plates near and parallel to each other varies as their area, and inversely as their distance. In what units are we to measure capacity? If we have already chosen a unit of resistance, a unit of capacity must follow from that through the units of potential and current. It would be the capacity of that condenser which, if brought to unit difference of potential, would discharge a galvanic current whose

time integral was unit current for unit time. It would be quite natural to define as a unit of resistance the resistance between opposite faces of a cube of a defined substance at a defined temperature, in which case the dimensions of resistance would be the reciprocal of a length. Or, again, we might lay by a piece of wire and carefully preserve it, and say, let that be our unit of resistance. Then resistance would have no dimensions in terms of mass, length, and time—it would be a fundamental unit. In either case we should introduce physical constants into our formulæ for electrostatic and electro-magnetic phenomena, depending in the one case on the physical properties of the substance chosen, in the other on its actual dimensions. If the history of electrical discovery had followed the course adopted in this discourse, and it had become necessary to fix upon a unit of capacity at the point we have now reached, it would have been very natural to have taken the capacity per square centimetre of two plates at unit distance, the insulating medium being vacuum. We shall see shortly what is the actual electrostatic unit which has been chosen, but the fact is there is nothing specially natural, nothing specially absolute in the choice.

It is a matter of very great interest to know the capacities of condensers of various forms. Let us take, for example, the case of a sphere enclosed concentrically within another sphere. If r_1, r_2, be the radii of the two spheres, the result is that the capacity varies as $\frac{r_1 r_2}{r_2 - r_1}$; if r_2 be very great in comparison with r_1, the capacity varies as r_1. The electrostatic unit of capacity ordinarily adopted as absolute is the capacity of a sphere of unit radius enclosed concentrically in a very great sphere, with vacuum as insulator. From this, remembering that the product of a difference of potential and a galvanic current shall be power in ordinary mechanical units, all other units will follow. Thus time integral of current divided by difference of potential or capacity is a line; therefore conductivity is a velocity, and resistance the reciprocal of a velocity. Difference of potential multiplied by current is power, and has dimensions $M\,L^2/T^3$, but potential divided by current has dimensions T/L; therefore current squared has dimensions $M\,L^3/T^4$, and current $M^{\frac{1}{2}}\,L^{\frac{3}{2}}/T^2$, and so on.

Again, the capacity of two plates, area A, distance x, can be deduced from that of two concentric spheres at a small distance apart: it is $A/4\pi x$ in these units.

We may now prove that mechanical forces must exist between the plates of a charged condenser. Let a condenser be formed of two parallel plates of area A at a distance x from each other, the distance x being capable of variation; let the condenser be charged to a given difference of potential, and then insulated, and the position of the plates in relation to each other varied. If the condenser be then discharged, it is found, first of all, that the total discharge is the same however the position of the plates be varied. Suppose now that the condenser be charged to a difference of potential E, and a quantity, or time integral, of current Q, the work done in so charging the condenser will be $\frac{1}{2}$ E Q. Let now the condenser be insulated, and the distance of the plates increased to $x + \delta x$: the capacity of the condenser will be diminished in the ratio $x/(x + \delta x)$; and therefore, since the quantity remains the same, the difference of potential will have increased to $E(x + \delta x)/x$. Now discharge the condenser. The work done by the discharge will be $\frac{1}{2} E Q (x + \delta x)/x$, or an amount of work $\frac{1}{2} E Q \delta x/x$ greater than was done in charging the condenser. This work must come from somewhere. The only way in which it can be introduced is by the work done in separating the plates from each other. To increase the distance between the two plates by an amount δx therefore requires that we shall do mechanical work $\frac{1}{2} E Q \delta x/x$ upon the plates. This mechanical work is done through a distance δx, therefore a force must be exerted in separating equal to $\frac{1}{2} E Q/x$; hence it follows, as a matter of necessary consequence from the laws of the capacity of conducting surfaces in the presence of each other, that those surfaces shall when charged act mechanically upon each other; and the amount of mechanical force is determined.

Now $\frac{E A}{4\pi x}$ is equal to Q, hence the force between the plates is $\frac{2\pi Q^2}{A}$. Let us now suppose that matter is laid upon each plate of density $\frac{Q}{A}$, and that the matter on one plate attracts that on

the other plate with a force varying as the inverse square of the distance: the resultant attractive force between the plates is exactly $\frac{2 \pi Q^2}{A}$; hence we should accurately express the facts of attraction of two plates if we said there is on each plate a charge of electric substance, and every particle of substance on the one plate attracts every particle on the other with a force varying inversely as the square of the distance. But that the facts can be so expressed is no evidence that any such electric substance exists.

I do not propose to touch on electro-magnetic and magnetic phenomena; I would only point out this: Just as electrostatics has been based on action at a distance between hypothetical electric fluids, so magnetism has been based on the action at a distance of hypothetical magnetic fluids. There can be no doubt that the science could be easily rearranged, and that the phenomena of electro-magnetism could be made fundamental, and that the facts concerning permanent magnets could be made subsidiary thereto, exactly as we have deduced this evening the facts of electric attraction from the phenomena of current-electricity. I believe that in the future this is the way the science must be arranged for practical men. They are but little concerned with the attractions between charged spheres and the like, and very much concerned with the laws of currents and differences of potential and capacities. The theory of permanent magnets has for the modern electrical engineer only a general interest, but the laws of magnetic circuits and induction therein are all-important. It would seem that the subject needs rearranging, and that that which is most important should be put most prominently forward. I even venture to think that this would be no loss to pure science; we should see with increased clearness how little we know what electrical phenomena really are, and how much we know of how electrical laws work. We should see how much there is that is arbitrary and conventional, and by no means absolute, in the system of units we have adopted. The science of electricity is so essential to the practical electrical engineer that it

should be arranged so that he can learn in logical order what he most wants to know. In what I have briefly indicated there will be something which is trite to all, and something perhaps not easy to comprehend when stated too shortly. My aim has been rather to excite in your minds discontent with the way in which the science of electricity is usually arranged, in the hope that such discontent may take an articulate form, and become a demand for something more convenient for your particular purpose. When the demand becomes clear it will not be long before it is supplied.*

Professor SILVANUS P. THOMPSON: Mr. President and gentlemen,—Very unexpectedly there has been entrusted to me a resolution to move. It is—"That the thanks of this meeting "are due to the President for the interesting Address just "delivered by him, and that he be requested to permit its "publication in the Proceedings of this Institution." We cannot, Sir, thank you too heartily for the stimulus which you have given us to modernising the science which this Institution is established to promote, and over which you are to preside during the coming twelve months. I am one of those who have long felt that we were too much bound by the methods, the ideas, and the language of those who have preceded us; and if we can manage to dispense with the antiquated ways of the last century, and adopt your suggestion of living in our own century, I am sure, not only that we shall be gainers, but that our science will also gain. There is nothing to regret, Sir, in your new mode of treating electrical subjects. It is not altogether new to some of us. I had hoped it might have been still more modern, and that, as you have left aside electrostatics altogether, you might have based yourself on the dynamo rather than on the antiquated galvanic cell; but that is by way of criticism. We thank you very heartily, and are

* I am informed by Professor S. P. Thompson that he has for some time past in his lectures begun the subject of electricity with the consideration of currents. My attention has also been called to Professor Ayrton's excellent book on "Practical Electricity" (1886), and to Dr. Walmsley's book on "The Electric "Current" (1894), with the contents of which I ought to have been, but was not, acquainted, in which a similar arrangement of the subject has been adopted.—J. H.

Jan. 22nd.

glad to recognise that you are among those who deem it an honour to teach. We also beg you to allow your Address to be printed in our Proceedings.

Professor A. B. W. KENNEDY: It gives me very great pleasure to second the motion of Professor Silvanus Thompson—a motion which has already been received in a perfectly unmistakable manner by the meeting. A very large number of members of this Institution have, unfortunately, passed a certain age; and when they have passed a certain age it follows, as a matter of course, that the electricity they learnt was of the century before last, and that when they had to work with another kind of electricity they found there was a great gulf fixed between the two—and to some of us, I am afraid, that gulf is only just beginning to be bridged over. I think, Sir, that if you have helped forward, from the academic side, the education of the coming engineers in such a manner that that gulf shall no longer for them have any existence, you will, in that alone, have added in no small measure to the many matters for which we are all so much indebted to you. I have very great pleasure in seconding Professor Thompson's motion.

The motion was carried with acclamation.

The PRESIDENT, in reply: Gentlemen,—I thank you very heartily for the kind way in which you have received my humble efforts this evening. I fear they have been very imperfect, but I confess I feel I have some excuse in the very short time that has elapsed since I knew that this important office would be placed upon my shoulders.

I have to announce that the scrutineers report the following candidates to have been duly elected this evening:—

Foreign Members:

Charles M. Hall.
Christian Vilhelm Kursch.
Felix J. L. Mélotte.
Louis de la Peña y Brãna.
C. Poulsen.

Member:

A. M. Billington.

Associates:

Frederic J. Anson.
Henry Carr.
Arthur Dalby Chamen.
Henry Coles.
Thomas Davis.
Herbert R. Harper.
Thomas Edward Ingoldby.
Leopold Lucas.
William Maurice.
William Bourchier Nicholson.
John Francis Pawsey.
John Horace Reeves, M.A.
Arthur Dudley Southam.
James William Speight.
William Edwin Toll.

Students:

Ernest Bernstein.
John Muir Donaldson.
George L. Eynon.
Charles C. Garrard.
Frank Graham.
Selwyn Seafield Grant.
E. B. Gray.
Walter Hall.
Leopold H. Harris.
T. A. Kerr.
Arnold G. Livesay.
Edgar Walford Marchant.
H. R. Mott.
Harry Charles Weston.
Harry George Whiting.
Arthur Stanley Williams.

The meeting adjourned to January 23rd.

The Two Hundred and Eighty-third Ordinary General Meeting of the Institution was held at the Institution of Civil Engineers, 25, Great George Street, Westminster, on Thursday evening, January 23rd, 1896—Sir DAVID SALOMONS, Bart., M.A., Vice-President, in the Chair.

The minutes of the ordinary General Meeting held on January 16th were read and approved.

The names of new candidates for election into the Institution were announced and ordered to be suspended.

The following transfers were announced as having been approved by the Council:—

From the class of Students to that of Associates—

Harold William Clayden.	James Mathieson Macfie.
Arthur Clifford.	Herbert William Miller.
Frederic Digby Latimer.	Charles Barnard Wigg.

Mr. D. Bates and Mr. R. C. Clay were appointed scrutineers of the ballot.

Sir D. Salomons. The CHAIRMAN (Sir David Salomons, Bart.): It is only one week since that we met in this room in a joyful spirit to move a resolution to tender our services to Her Majesty to assist her in case of need, to defend her throne and her country. In one short week these feelings of pleasure have been converted into those of sorrow. A cloud has come over the Palace. A very estimable and venerable Sovereign, an excellent mother, and a good woman, has lost her Son-in-Law, and a beloved Princess of ours has lost, in this world, her Husband. We know well that when there has been a calamity in this country or in any other country afflicting any number of people, or even a single person, Her Majesty has always been the first to sympathise with them in their grief. At such a moment as this, we, as Englishmen and men, quite apart

from our nationality, join our hearts with those of the Royal Family, when the Queen and the Princess are so distressed, in expressing our deep grief and sympathy with them in their trouble. I will ask you to pass a special resolution (that it may be transmitted to the right quarter) expressive of the great regret with which the Institution has received the news of the untimely death of His Royal Highness Prince Henry of Battenberg, and that the members desire to be allowed to lay before Her Most Gracious Majesty the expression of profound sympathy with Her Majesty and the Princess Beatrice in the great bereavement which has overtaken them. This resolution requires no seconder, although I understand that a Member of Council who has been in the Army for many years, and who has naturally, in common with us, feelings of loyalty to the Throne, will say a few words, so that it may go from this meeting of the Institution not only as the expression from the Chair, but also from the Council and from the members, that this resolution is not merely one of form, but one of true sentiment on our part. Sir D. Salomons.

Major-General Webber, C.B.: In conformity with the wish of the Council, I have great pleasure in being allowed to add a few words to those in which you, Sir, have so eloquently expressed the feelings which I have little doubt will be in the mind of all those present to-night. Sir David Salomons has suggested the propriety of my saying a few words, but I shall only ask you to remember that it was in furtherance of a great wish to identify himself with the Volunteer Service of this country, to which he already belonged, that caused Prince Henry of Battenberg to volunteer to join the forces going to Ashanti, so that he might have the opportunity of seeing some active practical service in the field. Nothing, however, ensued to give him that opportunity, although a great deal of practical work was done without a shot being fired. On the one hand, this absence of fighting was a matter of joy to the country, but, on the other hand, it was joy tempered with grief, as it resulted in the loss of the life of a man whom, if we did not know him personally, many in late years have learned to regard with great friendliness. I am not seconding the proposition, but I simply add these few words in Maj.-Gen. Webber.

Maj.-Gen. Webber. confirmation of what our Chairman has so eloquently placed before you. I am sure it will be passed by acclamation.

The motion was carried unanimously.

Sir D. Salomons. The CHAIRMAN: We will now proceed to the business of the evening—the discussion on the two papers which were read on the 28th November, viz.: "The Electric Wiring Question," by F. Bathurst, Associate; and "Concentric Wiring," by Sam. Mavor, Member.

Mr. Geipel. Mr. W. GEIPEL: Now that the existing rules of the Institution for wiring are on the point of revisal, the two papers under discussion have an additional importance apart from the mere relation they have to the two particular methods advocated by their respective authors. I endorse cordially the point urged by Mr. Bathurst as to the principal obstacle to the general adoption of electric lighting. It is undoubtedly the expense of wiring the building. Those of us interested in the supply of electricity are doing our utmost to reduce the cost of supply; the lamp manufacturers, as to the expense of lamps, are doing likewise; and yet, to judge from the tone of the remarks made at the recent Board of Trade Conference, an attempt is being made by some of us to increase this cost of wiring through raising the standard of insulation to an unnecessarily high pitch. If, as I believe is the case, we are all desirous that electricity should benefit mankind to the greatest possible extent, then do not let us saddle this work of wiring with more unnecessary conditions than we can possibly help. By all means let us protest against shoddy work, but do not let us put on needless refinement. Some of the rules of supply undertakings stipulate for as much as 75 megohms per lamp—quite an unnecessary standard. We know that such rules are quite untenable unless confirmed by the Board of Trade, and it is satisfactory to think that the persons really interested—namely, the insurance companies—are so far much less drastic. The Phœnix is 12·5 megohms per lamp; and 25 other leading companies stipulate that the leakage is not to exceed 1-20,000th of the total current, which, at 100 volts, = 2 megohms only per ampere; while the present rules of this Institution are 1-5,000th of the total current, = ½ megohm per ampere, or 1-150th part of that I first mentioned: this appears to be quite adequate.

I regret to see, also, a tendency amongst the engineers of L.T. systems to force a 200-volt supply upon the consumer. Wiring contractors will do well to join the consumers and protest emphatically against this practice—at any rate, until such time as absolutely reliable and cheap 8-C.P. lamps are obtainable for this pressure. Meantime it is sufficiently difficult to get 100-volt 8-C.P. lamps which will stand burning at an economical efficiency. It must be remembered that for economical reasons the renewals of 8-C.P. lamps should be less frequent than larger C.P. lamps, as there is a definite ratio between cost of current and renewals. The life of an 8-C.P. lamp should be about $\sqrt{2}$ times that of a 16-C.P., assuming that each lamp costs the same. Mr. Geipel.

The first question occurring to all of us is, Do the methods advocated by the authors tend towards economy in first cost? I am afraid that this question is not answered by any reliable data; in fact, there is a noticeable absence in both papers of any figures as to cost. Perhaps the authors will give some data in their replies. In urging the advantages of his system Mr. Bathurst says that he saves on the insulation, which is half the cost of the wires. Yes, but at what expense? Does he maintain that his tubes are supplied and fixed for the same price as the much-abused casing or compo tubing? I opine that he cannot, more especially as he speaks of the necessity of trained workmen. In my opinion the extensive use of casing is largely due to the fact that there are always plenty of joiners to be had who do the work without special training. In speaking of the advantage of high insulation of his wires, I am afraid Mr. Bathurst forgets that the really weak points are in the switches, cut-outs, and fittings. What Mr. Bathurst means by the actual strain $C^2 R$, I cannot understand. $C^2 R$ is simply a watt, and watts, as we all know, are different to a "strain." And with regard to the previous sentence in his paper, should it not read, "with two faults in the pipe," &c., and not, as he has it, "two conductors"? Perhaps he will make these two points clearer to us in his reply. Nor can I follow Mr. Bathurst in his statement that rust in pipes is unfavourable to insulation. Rust is a better non-conductor than unoxidised iron.

Mr. Geipel. I have listened with great interest to Mr. Mavor's description of his well-thought-out system of concentric wiring, but I hope that the members of this Institution and the fire insurance companies will not be alarmed at Mr. Mavor's somewhat pessimistic remarks and warnings as to the necessity for greater stringency. I cannot at all agree with Mr. Mavor as to the unsightliness of wiring in the present system. Why, there are numbers of houses in London where not a casing is visible; and I am not sure that, if his concentric cable "blunders across ceilings and cornices," it would look one bit better than casing put up in such a negligent manner. No! it is useless to attack the existing method on the score of unsightliness—cost alone is its vulnerable point; and unless the cost of the concentric wiring is about 50 per cent. less than it was about a year and a half ago, I am afraid the concentric system is not ready yet to help us. I speak from experience, for about that time I got a quotation from a firm who make a speciality of this system for wiring a large mansion for about 1,000 lights.

In the foregoing remarks I do not wish to discourage in the slightest either of the systems; by all means let us encourage the fire offices to give them every chance of proving their worth. It is possible that by abolishing the insulation of the outer conductor the concentric system might become cheaper than casing. *Indeed, I am of opinion that the Board of Trade might go a step further and dispense with the insulation of the "outer" of all concentric L.T. distributing mains.* It might be necessary to slightly insulate the outers of the feeders to obviate telephonic interference and electrolysis, but the difference of potential between any parts of the distributing network is so small that there appears little necessity of insulation, especially as the outer is, even when insulated, invariably at earth potential. With such a system a considerable saving in first cost could be made, while Mr. Mavor's concentric system with uninsulated outer would work well in with it. As to the soldering of all contacts, this necessitates the use of a soldering iron whenever a fitting or switch requires disconnection or connection to the circuit. Is not this an objection, as compared with the readily made mechanical contact? I agree entirely with Mr. Mavor's remarks as to the

importance of what he describes as grouping the branch fuses at distributing centres, and consider that the method should be made compulsory with all systems of wiring, especially as it involves no increase in first cost. I also agree with Mr. Mavor's strictures upon the bayonet joint lamp-holder so much in vogue, and I would ask if any of the members can second my experience, which goes to show that the Edison screw socket is a better holder? while it certainly appears to overcome Mr. Mavor's objection. Mr. Mavor admits that a fault may be caused in his wires—by a nail, for example—yet he proceeds to argue that he may sink his wires in the plaster, as it is never necessary to remove them. I cannot agree with that. The compo tube provides a means of repairing the wires in such cases without destroying any decorations. Mr. Geipel.

If I may be a little hypercritical, I would suggest to the authors the unsuitability of the word "lead." Is not "conductor" a much more appropriate term? I am aware that in the Fire Risk Rules of this Institution these terms are mixed up together, even in the same clauses. I do not, however, see the object, unless it is to give each term a turn, and show that "there's "no ill feeling." I hope, however, that "lead" will be dropped in future rules.

Mr. H. W. HANDCOCK: It is a great pleasure to see the prominence that has been lately given to iron piping. There is also a general idea that the time has now come when we should make a move with regard to our old friend the casing. I venture to think, on examining the iron pipe system before us on the table, that, although it is a step in the right direction, it might possibly be carried a little further. I am not altogether sure that insulating our piping and reducing the insulation of the cable is exactly the right thing. In the first place, by putting this insulation inside the pipe we reduce its capacity a great deal. In the second place, we are not altogether terrified when we are told, as some people tell us, that the life of vulcanised rubber is, we will say, three years. If that is the case, I should like to ask Mr. Bailey, for instance, in the case of the hundreds of thousands or millions of pounds' worth of vulcanised cable under his control, whether he anticipates the depreciation of that cable will be $33\frac{1}{3}$ Mr. Handcock

Mr. Handcock.

per cent. I should like to hear what the makers have to say on that point. Without laying any particular claim to a system of iron piping, my partner and myself venture to think that we have been to a certain degree instrumental in promoting its introduction. We are aware that for some years past there has been a feeling among many that there is room in the electrical world for more engineering spirit, so to speak. The casing was not satisfactory: it did not comply with the many requirements that one was justified in asking of it. We know that for some time past there have been on the market various iron piping systems, but somehow or other no one has cared to take the plunge. We are gratified to notice, however, that of late, since we determined to introduce it into the Commercial Union and Guardian buildings and others, it has certainly increased in favour; and it is a system which presents many advantages when lighting new buildings. First of all, it is a system which can be put in the walls while the building is going up. The builder generally prefers that. He can mix his mortar on the top of such an electrical lighting installation. It is not necessary when the building is finished to pull half of the work out again. The ubiquitous carpenter cannot drive his nails through the electric lighting pipes, and that is a considerable advantage. We find that we have in iron piping with suitable draw-boxes a system which enables us to put in the whole of the pipes while the building is going up; it enables us to draw in the cables the last thing, so that we start with an installation which is new; we do not start with an installation which, as often happens with casing, is three parts worn out before it is put into use. We also find with iron piping that, by a proper arrangement, and insisting on the contractors drawing in their wires after the piping is erected, it is very easy to replace a defective cable at any time. In electric lighting as put in at the present moment the questions of disturbing decorations is, I am afraid, not considered sufficiently, should it at any time be necessary to inspect the wires underneath. It is necessary in piping work to take suitable precautions. All the joints must be vulcanised. It is not sufficient to have good materials; one must have good workmen

also—a point, I am afraid, often overlooked in electric lighting. With good workmen and second-class materials you can make a passable installation; with first-class materials and second-class workmen you never can. Passing on to another matter—namely, the question of insurance—there is no doubt that for the past few years there has been a certain amount of feeling with regard to the matter. Is it not because the function of the insurance companies has been misunderstood? The insurance inspectors have a difficult task to carry out, and I am very much afraid that the public have been under the impression that because an installation is passed by an insurance inspector it means that it is safe, that it is perfect, that it is ideal, and that nothing can happen. Let us consider what it means. Insurance companies, like other people, have to be guided by business considerations. If any company were to follow the ideal and simply say, "We will take nothing but perfect installations," it would mean that, on account of competition, people would step across the street and transfer the risk to a rival office. It is a question of competition. These gentlemen who represent insurance companies have to ask themselves this question: "If this installation is passed "as it is, will there be a greater risk than is incurred with the "previous illuminant? If there is a greater risk incurred by "passing this electric lighting installation as it is, then we must "put up the premium." On the other hand, supposing there has been a certain premium fixed for a building when it has been lighted by gas, it is evident that, if dangers due to electric lighting are not greater than the dangers due to gas, that insurance company is not justified in putting up the premium. It is evident they do not contend by this inspection of the installation that they have reduced the risk. If they did so, I think possibly in some cases the premium would be reduced; and, as far as I am aware, that is a thing which is very rarely done. It is a pity that it cannot be made known, or, at all events, driven home to the public in some way, that insurance companies—I think I am right in saying so—do not pretend to undertake the function of consulting engineers, and half a dozen other things rolled into one. They inspect the installation, and if they consider that the

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premium now being paid covers the risk, well and good; if not, the holder of the policy will say, "What point is there you object "to? What is there to prevent you accepting this at the ordinary "premium?" Naturally they will say, "We want extra switches, "extra fuses, as the case may be." To go a step further. We have to be guided a great deal in laying out electric lighting installations by the requirements of the insurance companies. Supposing the Institution of Electrical Engineers tells us how we are to wire a building, and what is required, should that be binding upon insurance companies? I think not. The rules of the Electrical Engineers should form a code to which anybody could refer who wants to know what, in the opinion of experts, is the best thing to do; but to be told by insurance companies that we must alter our system of wiring because it does not come up to the ideal, would scarcely be right. Possibly as time goes on that will be recognised, and a great deal of misunderstanding will be removed. One cannot help being struck, considering the difficulties which insurance inspectors have to encounter, with the fact that they do their work well, and have regard for the interests of all concerned. There are one or two points I should like to mention in connection with the declarations which we are generally asked to fill up for the insurance companies. In the first place, it happens that in some of the companies' forms we have to answer this question—"What excess of current will "the conductors safely carry?" I venture to think that there are no two members in this room who have the same opinion on that point. We personally generally settle the question by saying, "The current-density is so much to the "square inch," and leave the rest to the inspector. Is there not room for the Institution of Electrical Engineers to draw up a brief and precise table—to make a standard? The present method of taking out cross-sections for house wiring is often unscientific and wasteful. In the smaller sized cable you may safely run up to 2,000 to the inch; whereas when you get up to the larger sizes it is often not safe to exceed 500 to the inch. What the average contractor wants is, not a rule to perplex him, but a definite table that he can refer to at once, and ascertain that a certain size cable will

carry a definite current and no more. If he exceeds that, it is dangerous; if he keeps below it, he is on the safe side. Naturally, as one gets up to the larger sizes in the tables, the chief consideration should be temperature, whereas in the smaller sizes it should be fall in voltage for a given length. Then, again, another question we are asked very often in insurance companies' forms is: "Is the length of cut-out proportional "to the electro-motive force?" That too, is rather a difficult question to answer. In the first place, it lays no standard down for us, and we have to choose an arbitrary standard of our own. Take the Metropolitan Company, for instance. They bring into houses 2,000 volts, and transform down to 100 volts. It is evident, if we decide that the cut-out on the secondary should be 3 inches long, the cut-out on the primary circuit ought to be 5 feet long. There is something wrong here. On the other hand, if the Metropolitan cut-out is the right length —4 or 5 inches—the cut-out on the secondary should be one-fifth of an inch. I think it would be an advantage if this question were amended in some way. It is evidently an oversight. Then to pass on to the burning question of the moment: Are we to have in the future 50 volts, 100 volts, or 200 volts in our houses? It is a question that is capable of being looked at from many points of view. If you look at it from the point of view of the central station engineer, you will say at once, "Have 200 "volts." If you look at it from the point of view of the ordinary contractor, who has to take what fittings he can get on the market at the moment, and does not wish to expend too much on cables, you will say, "100 volts." If you look at it from the point of view of the consumer, I think you will probably say, considering the life of a 50-volt lamp, and the convenience, "50 volts." Many people consider that 50 volts is old-fashioned, and I venture to think that it is, from some points of view; but, on the other hand, it has very considerable advantages. We find that, if we specify half the cross-section of copper in our cables, it does not make anything like the difference in the cost of the installation which the advocates of the higher voltage would lead us to believe. It is a curious thing that, if you specify, we will say 50 volts, and

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then you afterwards reduce the cross-section of your copper by one-half for 100 volts, you do not get any important reduction in your tender. That is a matter which probably contractors can tell you more about than I can. With 50 volts and ordinary conditions in London, it is something astonishing what the life of lamps is at the moment. There are many places where we have had lamps running for four or five years, and still they go on—there is no sign of their giving out. It is a pleasure to have to do with such an installation, as there is no trouble. Lately, apparently, all makers have had batches of unfortunate lamps. I do not know what has happened, but apparently on all sides we are far more liable now to that sort of thing than we were in the past. What may we expect with 200-volt lamps? When we get up to 100 it looks as if what one may call the limit of convenience is reached; that is to say, although the consumer may save a little in first cost by adopting a higher voltage, we do not think this dubious economy counterbalances the advantages of convenience as regards the life and efficiency of the lower voltage lamp. At the present moment lamps are run in London under very trying conditions, owing to fluctuating voltages. When we stated a few weeks ago that at the present moment it was rather premature to advocate 200 volts, we were told, in the first place, that when we had experience in the matter we should think rather more of it; we were told that the life of 200-volt lamps was something remarkable; we were told that they were portable, that they did not break in transit, and several other things. We have had experience with 200 volts, and still maintain that this pressure for indoor work is an experimental stage. It has to come; but certainly the makers of fittings are not ready for it. It will come; and those who are using it at the present moment are doing us a most useful service. It is in the experimental stage. Then there is another point. When the voltage is increased to 200 it is an admirable thing for the central station engineer, because it increases the capacity of his mains and reduces the efficiency of the lamps: that is to say, a 200-volt lamp of the same candle-power will absorb approximately 4 watts per C.P., as against 3 watts per C.P. for a

100-volt lamp, so that the consumer is compelled to take $33\frac{1}{3}$ per cent. more current in order to obtain the same amount of light; nor will the admiration of the latter for the plan be increased if he accidentally gets a practical demonstration of the fact that with a three-wire system, 200 volts each side, it is occasionally possible to get a shock of 400 volts in his own dwelling, although the actual voltage of his installation may be only 200. Mr. Handcock.

Mr. J. HARDIE MCLEAN: I should like to look at the question from a central station engineer's point of view. We have been hearing a great deal about details in connection with wiring, but my opinion is that even with the old-fashioned wooden casing we could have a great deal better wiring if a little more attention were paid to the work of wiring on the consumer's premises. It affects central station engineers to a terrible extent, and I do not think we half realise it. We have to earn our bread and butter by grinding out current to these consumers. We are not paid for looking after their work, but we are supposed to do it. We are up early in the morning looking after the company's business, and we are up late at night looking after the supply to consumers. In addition to that we are expected to inspect and to look after the wires on the premises. In a small town like Oxford, it sometimes happens that there are six or seven or a dozen installations at the same time; and if you have to walk, say, half a mile between one place and another, and inspect every little bit of wire, there is not much time left for us to look after the company's business. Still we are expected to do it. To my mind the most serious point is this: If we neglect this work and there is an electrical fire, the credit of the company, or the concern, is at once called into question. But I look at it from a personal point of view. Where does my credit come in if I have a fire and it is said that it was owing to the bad wiring? Where should I be? I should like to see the fire insurance companies pay a little more attention to their own business, and let us pay more attention to ours. It very often happens that the work is finished before we receive an application form. When we go there the customers will not allow us to lift up floors and pull about ceilings in order to look at the wires. We simply have to Mr. McLean.

Mr. McLean. content ourselves with a casual inspection and the ordinary test. It seems to me that, unless fire insurance companies send their inspectors to look at the job, instead of sending on a long paper with 50 questions to answer—which, by the way, the contractor has to fill up—the quality of the wiring will never go up. These things on the table may be very nice. We see little tubes, and all sorts of joints and connections, but I could show you just as neat things with the old-fashioned wooden casing. How many of those things are you going to find underneath floors and behind plaster, I should like to know? I have been kicked about by the foreman of jobs simply because I would not pass the work. I have had the principals of the contractors come down to my office, and they have nearly kicked me out of my own office. A gentleman has just spoken about 200 volts, and he has said one or two things that are true, and some things which I do not agree with. I should like to say, from my point of view, I am inclined to think that, if 200 volts are turned on at some of the installations at the present time, the light will not be at the lamp,—it will be somewhere else! I was very glad a few weeks ago, when I attended the Board of Trade meeting, to find that we are going to have a little more power put into our hands. At the present time we are only supposed to be "reasonably satisfied" that the work is right. It depends whether the inspector is easily satisfied or not. I am glad to see one clause inserted there, namely, that if insulation falls below a certain point we are bound to cut them off. I will cut them off. I do not think I have very much more to say, beyond touching upon the insurance of buildings. At the present time insurance companies are threatening to raise the premiums of central stations. I wish they would look to consumers' houses and leave us alone. We spend a great deal of money in building fire-proof buildings: we have got iron and steel engines; we have flagged floors, steel and iron columns; and we have not got, perhaps, more wood about the building than I could weigh myself with. Still, they say they are going to raise us up from 2s. 6d. or 3s. per cent. to 10s. 6d. That will have the result of people looking to the amount of damage which would be done if a fire were to break out

at the central station when we were all asleep, and insuring up to that amount only. We in Oxford are insured for over £20,000 at the central station alone, and it would be a very serious thing to us if the fire insurance company was to double or treble our premiums. The additional premium would give me two more men in the engine room to look after the engines. Mr. McLean.

Major-General WEBBER: This question of fire insurance is one which is coming very close home to us electrical engineers at the present time, especially in connection with the various facts mentioned by the last speaker. The fire insurance companies are so irrational as to raise the premiums on buildings which are constructed, you might say, practically incombustibly. They are overlooking the great fact that electric lighting, when it is properly carried out, has rendered fire risk much less than it ever was before. There is a large field for the application of the electric light which, on account of the practical prohibition of the insurance companies, has not yet been occupied. In all our large seaport towns there are great warehouses where the fire insurance comes up to something like from 7s. to 15s. The owners are told that, if they displace the present defective and dangerous means of lighting and put in electric light, they will get no reduction, and therefore they do not care to go to the expense. I have seen a great many of these warehouses. We know when they catch fire the loss which falls on the insurance company is very heavy; but if the companies and their inspectors would only study the question—and they ought to have done it in the last 10 years—and make themselves masters of it, there is no reason why they should not reduce the rates with regard to that great mass of buildings largely situated in our seaport towns. And there is very little doubt that many warehousemen, if they could reduce their insurance by using electric light, would immediately put it in; but at present there is no inducement. The question of insurance is not only interesting to the supply companies, but also to contractors. If the insurance companies do not reform their ways, and reconsider and study the subject as they ought to do, competitors will grow up who will take the trouble to understand the diminished risks due to electric Maj.-Gen. Webber

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lighting, and insurance companies will be brought into existence which will be able to insure at premiums considered from that point of view. In that way, I believe, as the spread of electric lighting installation proceeds, they will get a very large business indeed. It is a matter to which the insurance world and the financial world might pay more attention. I shall not take up your time more than to mention that, in connection with all these systems of wiring that have been described to us in so interesting a way, it is even possible to wire your houses in a more simple manner than either by casing or by tubes or by concentric conductors; and, although I daresay I shall be called old-fashioned, I will mention my own house, in which the light has now been in use since 1886. The wiring is carried out by the conductors being attached to the face of the wall, 3 inches apart, with saddles; and wherever the lead of the conductor of the opposite pole crosses the wire beneath or above it to reach a point, it is simply separated by a specially made little sheet of ebonite, constructed in the shape of a saddle, which provides an insulation of not more than 3-16ths of an inch in thickness between the two insulated conductors. Those conductors have been on the walls for 10 years. The walls have been painted or papered more than once. I do not say they have been subjected to any violence, but so far as contact or injury is concerned they have never been interfered with, and there has never been in those nine years a short-circuit on any part of them. I do not mean to suggest that you should wire your houses in that way now, but to point out that it is a thoroughly practical and extremely economical way of wiring. It can be done at about 17s. per point when there are about 70 lights in the house. Wires so laid on the face of the wall are no disfigurement; the decoration covers them, and at any time it can be removed and the wires replaced. I only mention it as it is possible some who have thought of it also as I did at the time, may have used it and met with similar success and results.

I should also like to mention that I do not know any earlier standard wiring specification than the one I drew up and issued to the customers of the Chelsea Company in 1888. It was at the

time printed in some of the electrical journals, and at the present day there is very little in it that requires alteration. I have never seen cause to alter the clause which refers to conductors laid between floor and ceiling. It is specified that they shall be fixed wide apart, and not in casing or in a tube. When running parallel with the joists the two conductors should be separated by a joist. When lying in a transverse direction they should be laid in notches deeper than their diameter, cut in the top of the joist not less than 9 inches apart. Branches should be secured by cleats, or by passing through a hole in the joist, so as never to approach nearer the conductor of the opposite pole than 5 inches. Maj.-Gen. Webber.

In spite of the objections raised to casing, I am confident it will never be given up. In a short time we shall have it made with wood that is fairly incombustible, treated in such a way as to resist damp, decay, and so as to quadruple its normal insulating properties.

Mr. W. E. Langdon: I think we are very much indebted to the authors of the two papers under discussion for having brought to our notice not only, in the first instance, the special systems advocated in these papers, but for having—what is perhaps still more important—raised the very important question of wiring. The question is undoubtedly one of very great importance to the electric lighting industry, and anything that can be brought out from this discussion will be of material value to all those who are concerned, and especially to ourselves, with respect to the rules which are under consideration. I do not go so far as the authors in their general condemnation of wood casing. Wood casing has been undoubtedly of great service to the electric lighting industry in extending the use of the electric light; and it is a cheap means of doing so. Where it is considerately and judiciously employed, it is, in my opinion, calculated still to be of considerable service. There is no question that wires enclosed in metal tubing are safer than when enclosed in wooden casing; but still the wooden casing lends itself very conveniently to surface wiring. Where you have to deal with buildings which are already established—for instance, in a room Mr. Langdon.

Mr. Langdon. such as this—it would be very inconvenient indeed, and anything but agreeable to the eye, to wire the surface of the wall with tubing; but with properly moulded casing that is different; and where the walls are dry and the place for the application of the wooden casing suitable, there, I think, a great deal of service might still be obtained from casing. Another point, of course, is that of cost. Casing is cheap, and there is no law by which we may compel wiring contractors to use only certain articles. It is clear the factor of cheapness will always enter, and hence that which is cheapest will be employed to a greater or less extent. But there is one point with respect to this wooden casing that I should like to mention for your consideration. The wooden casing is provided with two grooves—one for the positive and the other for the negative wire. These grooves are a certain distance apart. The general practice of fixing the casing is by placing a screw or nail between these two wires. Eventually, if the insulation should become impaired, these nails and screws will tend to assist short-circuiting at that point. In my opinion the use of any metal whatever between the wires within the casing should be most carefully excluded. A rule has been adopted by me with respect to the Midland Railway Company for some time past, that where wires are placed out of sight—that is, above ceilings or below floors, and so forth—metal tubing should be employed, and that the use of wooden casing should be confined to the face of walls, where it may be always under observation. Possibly that regulation adopted elsewhere might be of service. But it occurs to me that this question is not entirely a question of conduits or casing, but it is one which has, in respect to wiring, a still more important side. On the occasion when these papers were read, I placed on the table some samples recently taken from a large installation. That wiring was carried out by a recognised trustworthy firm—one which had a great deal of experience—yet many of the joints were found to be dry joints, and I think I may say that in every instance the joints were found to be insulated with nothing but adhesive tape. If

we meet with this condition of things with a firm which carries out the work, not under a contract, but paid for at prime cost plus a certain percentage, what are we to expect from cheaper jobs where there is a fixed price, and where the contractor, of course, desires to keep the cost within the amount of his contract? It seems to me that here lies the whole crux of this important question. How are we to insist upon or obtain a better condition of things? Mr. Mavor, in his paper, if I remember rightly, threw out a suggestion as to inspection by the fire insurance offices—that the several insurance companies should combine together for the purpose of employing a man well versed in the matter, who should be able to give his whole attention to it, and so exact a better condition of things, or else cause the rejection of the consumer's connection. Let us consider whether that can be carried out in all towns. I am afraid that it will not be possible. It is an excellent suggestion, but there are many towns where I am afraid there would be a difficulty in securing the services of such a man; and of course such a man, to be of service, would require to be properly paid. But I would like to suggest for consideration whether it would not be much to the interest of the supply companies themselves to institute such a branch; to establish an officer competent for the duty, who should be empowered to inspect every installation as it progressed. You may say that the supply companies have the power now to reject any installation with which they are not satisfied, but the only means of satisfying themselves at present is by a cursory examination, or testing the connection. What occurs to me as desirable is that the supply companies should notify to intending consumers their desire to place at their service some one who should examine the work as it progresses, and give a guarantee of its satisfactory execution. This, I think, would lead to much better results, and would undoubtedly enforce a more careful consideration of tenders on the part of contractors. Mr. Langdon.

Mr. H. C. DONOVAN: The success of electric wiring depends, not so much on the superiority of one system over the other, but Mr. Donovan.

Mr. Donovan. on the way the work is executed. Partial failures in insulation are due, in most cases, to neglect of detail in the process of wiring. This question of aptitude for detail on the part of workmen and supervisors is a difficult one for employers, as there will always be men seeking employment who have no real aptitude in this respect. With them it is an innate mental deficiency, not to be overcome by either education or experience.

Experience gained by the Eastern and Eastern Extension Telegraph Companies in their efforts to maintain insulation in their land lines would be of great interest and instruction to the young men of this Institute. Every possible cause of loss of insulation has been met with. In some cases a land teredo has been a source of trouble in the past.

Mr. Antill. Mr. B. H. ANTILL: I think it is fortunate for the Institution that these two papers on electric wiring should be before it on the same evening, for this renders it easy for the members to bring the discussion to a much clearer focus than if the papers had been read on separate occasions. The impression left upon the reader is undoubtedly, I think, that each author considers the scheme brought forward by himself as the only one that fulfils the requirements of an efficient wiring system, and that any other scheme must be very imperfect indeed. The question therefore arises as to what course an experienced contractor is to take upon being confronted by two or more perfect systems of wiring; and I submit that the facts most clearly brought out by hearing the two papers together are that no one system is applicable in all cases, and that an experienced contractor must, and will, choose his systems of wiring as may best suit the local circumstances with which he has to deal. In this connection I may perhaps be allowed to draw attention to what I believe is the most conspicuous example existing of "open wiring," viz., that which is to be found at the British Museum, where the wires are supported clear of the walls on insulators of porcelain. This wiring has without question given the fullest satisfaction ever since it was first put up. Referring now particularly to Mr. Bathurst's paper, I find he deprecates the use of iron pipes for wiring purposes.

Yet he admits towards the end of his paper that his insulating tubes would not be efficiently protected against mechanical injury unless they were enclosed in iron or steel coverings. There is, so far as I can see, no real difference between such iron-covered tubes and iron pipes lined with insulating material. In either case, however, it would be highly improper to dispense with the employment of well-insulated wire. I am afraid I must cavil a little at the use made in this paper of the word "accessibility." From a perusal of the paper it would appear as if the author means by accessibility facility for renewal; for wires which are built into walls in tubes can only be inspected after having been drawn out of the tubes, and it may be considered as certain that no one would take the trouble to inspect periodically such a system of wires, but would only make an inspection after a fault had occurred and it became necessary to replace a portion of the wiring. Accessibility in such matters, I would suggest, really means facility for inspection—a facility which renders it possible to discover an incipient fault before it has had time to develop. Concerning the concentric system of wiring advocated by Mr. Mavor, it appears to me that the curve which Mr. Mavor publishes with his paper is misleading. I quite see the point which he wishes to make regarding the irregular employment of "wiremen," but I fail to see that the curve illustrates it. The curve in my opinion only shows that a certain number of lamps has been connected to the Glasgow supply mains each month during a certain period, and does not necessarily represent the employment of the "wiremen" over the same period. This becomes clear when you consider that a large installation might take some months to prepare, and would only appear on the curve to the credit of one particular month. There is one paragraph in the paper with regard to insulation resistance which has my full sympathy. Mr. Mavor writes as follows:—
"It is of much greater consequence to obtain a moderately
"high insulation which may be relied upon to be durable, than
"to have—as can easily be had in a dry building—an insulation
"resistance of many megohms which will disappear on the

Mr. Antill.

Mr. Antill. "approach of the charwoman and her wash-bucket, or is at "the mercy of the first loose slate or leaky water pipe." This is, I maintain, a principle which should be enforced not only in house-wiring, in the wiring of ships, &c., but also in the specifications issued for the cable networks of central electric light installations. The practice of attempting to ensure good and lasting cables by specifying very high insulation resistance defeats its own ends, because a high insulation resistance, as is well known, can be obtained by other means than by quality or thickness of insulating material. I do not wish to suggest to-night precise terms for a satisfactory cable specification, but my own opinion is that more reliance should be placed upon kind and quality of material, and upon thickness of the insulating covering, increasing with voltage, than upon hundreds and thousands of megohms. It can scarcely be insisted upon too strongly that a cable having a comparatively low insulation resistance is frequently a better and a more durable cable than one having a much higher insulation resistance; and also that, conversely, a high insulation resistance is not a proper criterion as to the permanent qualities of a cable. There is only one more point to which I wish to allude. There is no doubt in my mind that the concentric wiring before us to-night is to all intents and purposes a development of the single-wire system which Mr. John Raworth worked out many years ago in connection with ship-lighting, where he used either the ship as return, or concentric leads such as described by Mr. Mavor. The experience of the last 10 years has shown the system to be thoroughly reliable and satisfactory. I think the authors are to be congratulated upon their very interesting papers.

Mr. Swinton. Mr. A. A. Campbell Swinton: I think the discussion upon these two very interesting papers has rather suffered from the long lapse of time which has taken place since they were read; in fact, certain of the earlier speakers this evening appeared to be unaware that any papers had been read at all. With regard to Mr. Mavor's paper, I think that some people who are connected with the carrying out of electric wiring are under the impression

Mr. Swinton.

that this concentric system, though very excellent from a mechanical point of view, and very suitable for warehouses and factories and so forth, is not very suitable for highly decorated houses. I must confess that I was of that impression myself until recently, but some months ago I was given the opportunity by Messrs. Mavor & Colson to see an installation that they had recently carried out in a private house in the neighbourhood of Dumbarton. It was a very highly decorated house, and undoubtedly this system of wiring lends itself exceedingly well to the wiring of houses, however decorated they may be. There are certain advantages in respect of having practically only one wire, the other wire being uninsulated, which enables you to have exceedingly small switches and other fittings. These points are very advantageous where decorative effect is required. There is, however, it seems to me, one great difficulty with regard to this concentric system, and that is this: It is impossible in most cases for contractors to maintain two separate staffs of workmen. If they are going to carry out their work in the ordinary way with wood casing, certainly, if high-class work is to be done, a large portion of their staff ought to be of the house carpenter class. If, on the other hand, the work is to be done on the concentric system, you do not want carpenters at all—you want men more of the nature of plumbers. Men with the same experience are not always quite suitable in each of the two cases. Many of the larger contractors carry out town wiring as a way of utilising the spare time of their workmen when they cannot employ them more profitably for installations in the country where plant is required. This concentric system is at the present moment applicable where a separate plant is used. It is also applicable where alternating currents and a separate transformer are used. But it seems—at any rate, at the present time—that it is not applicable where the supply is taken from any of the ordinary continuous-current systems. I have at the present moment a case in point—a large institution near Edinburgh where I am at the present moment making a report with regard to the proposed electric lighting. It is a question there whether there is to be a separate plant, or whether the supply is to be taken from the

Mr. Swinton.

Edinburgh supply. It is a building which is exceedingly difficult to wire, and the ordinary system with wood casing is, in fact, almost inadmissible. I am quite sure the concentric system is the proper system to wire that building with; but I am met with the difficulty that the Corporation are unable to sanction a system of concentric wiring, for the reason that the Board of Trade will not allow them to have one of their conductors earthed except at the central station. If they would allow the conductor to be earthed at the feeding point it would meet the case, but they are only allowed to have the conductor earthed at the central station; and between the central station and the building there would be a considerable difference in potential, and consequently the concentric wiring with the outer conductor earthed is not admissible. It appears to me that that is a very important point. I think that where the concentric system is not admissible, wood casing, in the case of dry buildings, answers very well. In the case of wires that have to be buried in wet plaster I do not think the wood casing is advisable at all. It appears to me that iron pipes are worse, and, in my experience, they are an infinite source of trouble. I am inclined to think that Mr. Bathurst's tubing is a very excellent arrangement for this purpose. One gentleman has spoken this evening with regard to the amount of current that small wires carry without any danger. The same point is touched on in Mr. Mavor's paper, where he mentions that the same sized wire—a very large wire—is carried to all his fittings. I think it is not very generally known that proportionately very large currents can be carried perfectly safely by very small wires. I have made a few experiments to find out what can be done in this direction. I find that a No. 3 22 S.W.G. conductor—the ordinary sized conductor used for single lamps of 16 candle-power in the better class of installations—insulated with vulcanised rubber and put in a wooden casing in the ordinary way, will carry 26 amperes with very little heating. I have tried a conductor of this sort with this current for over half an hour, and the temperature only rose to 107° Fahrenheit. That is a current-density of 13,700 amperes per square inch, and it is perfectly safe. I also tried a 3/25 conductor. After 55

minutes this one with 26 amperes rose to 242° Fahrenheit. That is only a little over boiling water, and it is perfectly safe. I took it up to the point at which the temperature did not rise any further. I am not advocating the employment of these high current-densities in practice. I only mention them as I think there is a great deal of nonsense talked about the matter. Then I found that an ordinary piece of flexible cord of 36/38 wires would carry 10 amperes, rising to about 150° or thereabouts quite comfortably. It never gets any hotter as long as it is straight. Of course, when it is coiled up it gets warmer, but that is a current-density of 25,000 amperes per square inch. These examples might be multiplied, but the fact remains that with very small wires the high current-densities are perfectly safe. They are not advisable because of the drop in volts, and of course the case is quite different with large conductors or cables. Mr. Swinton.

Mr. G. S. Corlett: I had been myself rather sceptical about this concentric wiring, but latterly I have used it at two or three important installations, and I was agreeably surprised with one or two points in connection with it. The first was the very little difficulty we experienced in training our ordinary workmen to deal with the system; and, secondly, the cheap manner in which the whole job could be done. For example, the prime cost of wiring for 16-candle lamps in an ordinary Lancashire cotton mill, exclusive of the dynamo and switch-board, was something like 17s. per lamp. We had not the slightest trouble. An ordinary plumber could in half an hour make a joint as well as the trained man we got down to show us all about the system. It seems to me that there is a great deal of unnecessary prejudice about burying our wires in casings. Much has been said this evening about the desirability of having our wires accessible, but a great many of us, unfortunately, have to live in houses that are still fitted with gas pipes. I never yet heard of a householder being furnished with a chart of his gas pipes, so that he could avoid knocking a nail into any of them, which would cause a leak. Such accidents rarely happen. It seems to me that with this concentric system there would be no trouble at all from faults of this character With regard to the two papers generally, it would Mr. Corlett.

Mr. Corlett. have been interesting to put a certain number of statements that have been made by each author in parallel line, when it would be found that a large number of those statements are of a directly opposite character. For instance, Mr. Bathurst says that insurance men on the whole have done remarkably well. Mr. Mavor, on the other hand—I forget his exact words—as good as says that they have done just about as badly as they knew how. So far as my own experience actually goes, the present insurance inspection system is little more than a farce. A gentleman will come down to my office, send in his card, saying that he represents an insurance company. "What do you want?" I say. "I hear you have done an installation for Messrs. So-and-So." "Yes." "I want to know something about it." "What do you "want to know?" "Will it conform to the Phœnix rules?" "Yes, I think so." "All right. Good morning. That is quite "enough." It is accepted, and the policy is endorsed. Mr. Geipel alluded to the wickedness of the low-tension station people forcing 200-volt lamps on their customers. I have been using 200-volt lamps and 200-volt circuits for a long time, and I was waiting to hear in what particular the wickedness consisted. I have never found the slightest trouble in keeping up the insulation. We never have a larger proportion of faults in a 200-volt circuit than 100 volts. The only possible objections to the use of 200-volt continuous currents are, firstly, for arc lighting, four lamps are required; and, secondly, there is a little difficulty in obtaining very small motors for domestic purposes. I think the two papers we have before us will tend—or, at any rate, should tend—to raise the standard of wiring throughout the country. In my part of the world 14s. per lamp is not an uncommon price for ordinary shop wiring. I think you will agree that it is impossible to buy the material alone for an installation, properly carried out, at such a figure as that.

Mr. Geipel. Mr. GEIPEL: I should like to ask the last speaker, in order that there may be no misconception, whether the 17s. included profit; and whether it was the cost of wiring on the concentric system with the outer insulated, or whether it was for the usual method of uninsulated outer, which was so much cheaper than

the former. The objection to using 200-volt lamps is purely one of economy, combined with convenience. It is on the score of expense, and of trouble of lamp renewals, that I raised objection to the 200-volt system. Mr. Geipel.

Mr. CORLETT: I may say that the 17s. per lamp represented the job done with Mavor's concentric system, and did not include profit. Mr. Corlett.

The CHAIRMAN: The time is reached when it is usual to close our meetings. There are many other gentlemen who wish to speak, and then follow the replies of the authors of the papers; I therefore presume it is your wish to have the discussion carried on at the next meeting. If time allows, a fresh paper will also be read. I will now ask your indulgence to allow me to say a few words myself on what has passed, as I may not be able to stay after the Council meeting on the next occasion. I have personally very strong views on this question, which I need not express now, as many speakers have covered portions of the ground, though not all. I have always contended, and I shall continue to maintain, that inasmuch as when a man purchases a horse he would not choose that animal except for the purpose to which he intended to apply it, so that to run a race he would not buy a cart-horse,—in the same way with wiring, or anything else, you must choose your system according to the purpose to which it is to be applied; and it is ridiculous to lay down a hard-and-fast rule in favour of one particular system. In some cases it may be perfect, in others it may become expensive and unnecessary. A few words have been said on Fire Office Inspectors. I will give you an instance of how those gentlemen have been improved. It is not so very many years ago since the electric light was introduced into this country, and I was probably one of the first to use it. When the inspector from one of our great offices, which I will not name, came to see the fittings, I told him that he would find the cut-outs grouped together for certain sections of the house: he immediately asked me the meaning of the word "cut-out." After explaining to him that the object was to prevent fire, he was satisfied and went away. I do not think that a present-day inspector would be satisfied with such a short inspection. They have been educated, and by this Institution of Electrical Sir D. Salomons.

Sir D. Salomons.

Engineers. The Institution rules, which are now being revised in a most thorough manner, are not, as many suppose, intended to be followed rigidly in all cases. Whatever they may be when issued in their fresh form, the object is to show what a perfect installation should be; but I doubt if anyone could produce such perfection as the Institution lays down as possible, although it might be nearly approached in the case of buildings of a very inflammable character. In any case we shall be doing useful work in showing the world what is necessary under certain conditions. I have often pointed out to customers and householders that it is quite erroneous on their part to rest assured that everything is right because the inspector has passed the building, for the inspectors of Fire insurance offices are in a similar position to inspectors of a Life insurance office. If the latter were to pass only those men and women who are absolutely sound, it is quite clear that those offices would have to close their doors to-morrow. It is the average law of risks they go upon. With electric light installations they assume that a certain number will be burned down and that a certain number will not, and the average must come right for the office. The chief difficulty in connection with concentric wiring, good as it may be in numerous cases, is that the householder should be a man capable of making up his mind in advance—a very difficult thing when lighting your house in the beginning without having had experience of other forms of illuminants in the past, as in the case of a new house—since alterations are troublesome under this system. With the casing on the surface, which is always accessible, there is no difficulty in making an alteration if you change your mind and wish to have a light in some other part of the room, or many of the lights altered. The insurance, which depends so much upon the question of wiring, and which has been so unfairly dealt with in the case of central stations, comes very hardly on the company with which I am connected, for our insurances are nearly a quarter of a million. I hope engineers who have to do with central stations—and I believe nearly every man in this Institution will before long be called upon to perform duties there—will join together, put up their backs, and support *some organisation* which will deal in a fairer way with electric

lighting industries. To conclude my remarks, I would say that I have always kicked against outside interference, since every Englishman's house has so far been considered to be his castle; and I know that in the case of gas or oil lamps none of us here would allow an inspector to come meddling about our rooms in all directions, not knowing, perhaps, whether he was really an inspector duly authorised to see and dictate to you what you shall do and what you shall not do, or whether a burglar in disguise. I think this grandmotherly influence which is coming up at this moment—and which before many years we trust to see die out—is doing as much harm for the extension of the electric light as anything else. Numbers, you will find, do object to all this inspection. It brings an element of fear into their houses by the loss of independence, which we all so much value. I hope and trust we shall find a method before long of bringing about a good class of wiring, but we are anxious to secure it without interference with the liberty of the subject. Sir D. Salomons.

The CHAIRMAN announced that as the result of the ballot the following candidates were elected:—

Foreign Member:

A. E. R. Collette.

Members:

Francis Wm. Clements.
Patrick Walter D'Alton.
W. Fearnside Irvine.
George Robert Mockridge.

Associates:

George Frederick Adcock.
Howard H. S. Baker.
Edward G. C. Barton.
J. Augustus Bauer.
Selsey A. Cartwright.
Percival Bailey Clarke.
Valentine Corin.
A. T. Durrant.
Edmund Lewin Birkbeck Hill.
Charles Morison Johnston.
Horace Algernon Marler.
W. H. Miller.
William Moat.
Lieut. W. Montgomery, R.E.
Edgar Williams Newton.
George A. Pearson.
Charles Edward Peebles.
John Milner Shackleton.
Alfred H. Shepperd.
Frederick Martin Short.
William Rowan Wilson.

Students:

Benjamin Herbert Isidore Adler.
George Frederic Lewis Alexander.
William Frederick Bolton.
John Drayson Dymond.
Harold William Holder.
Frederick Watson Joll.
Hugh Sebastian King.
Algernon Lionel Lennox.
Laurence Moore Peel.
H. F. Platt.
Gabriel Arthur Madox Rossetti.
Edgar Stopford Saunders.
Harold Skipwith.
Frederic John Thompson.
Victor Watlington.

The meeting then adjourned.

ORIGINAL COMMUNICATIONS.

ELECTRICITY SUPPLY METERS.

By G. W. D. Ricks, Student.*

Electricity supply meters are, without doubt, the most important electrical measuring instruments used in connection with the supply of electricity from a central station. For, although it is of great importance to have accurate ammeters and voltmeters at the central station, their cost is of but little importance, as it is so small compared with that of the whole plant. The cost of supply meters, on the other hand, forms a most important item in the total capital expended on the plant, for one must be supplied to every consumer. In considering the expenditure for meters, not only must the initial cost be considered, but also the value of the energy which the meter absorbs, since this latter may even exceed the interest on the prime cost.

As an investigation of the effect of the absorption of energy in a meter on its cost is dependent on the class of meter under consideration, this point will be dealt with after the various kinds of meters have been described.

The function of a supply meter is to integrate the quantity $C \times V \times d\,t$, where C = instantaneous value of the current, V = instantaneous value of the potential difference, and $d\,t$ is a very small interval of time; or, to express this mathematically, to find the value of $\int_{t_1}^{t_2} C \,.\, V \,.\, d\,t$, t_1 and t_2 being the initial and final times between which it is required to measure the energy.

A meter which performs this operation is called either an ergmeter, joule-meter, energy-meter, or sometimes a recording wattmeter; this latter name is, however, a misnomer, as the

* Paper read at the Students' Meeting, January 24th, 1896.

instrument measures energy, and not power. Indeed, an energy-meter, far from recording the power in watts, gives by itself no indication of what has been the maximum, minimum, or even the mean power supplied. In practice, when the pressure is kept very nearly constant, the expression in the preceding paragraph may be simplified to $V\int_{t_1}^{t_2} C \, . \, dt$, V being considered as being absolutely constant; and the meter need then only measure $\int_{t_1}^{t_2} C \, . \, dt$. A meter which measures this quantity is called a quantity-meter or coulomb-meter.

If an alternating current is used, and if there is self-induction in the circuit, the energy given to the circuit cannot be measured by observing the deflections on a voltmeter and an ammeter and measuring the intervals of time with a watch, and multiplying these values together; for then the current lags behind the E.M.F., when this method would obviously be incorrect. A watt-meter and a watch, or an energy-meter, may measure correctly the energy given to a circuit by an alternate current.

Before directing attention to the various kinds of electricity supply meters, it will be well to point out the principal properties that a thoroughly good supply meter should possess.

1. Accuracy.

It is of primary importance that a meter should be accurate throughout its range. The enormous effect of a comparatively small error in a meter seems scarcely to have been realised. It may, of course, be argued that small errors are not of much importance, as when a large number of meters are being dealt with these errors will counterbalance one another to a great extent. This is, however, very questionable, and cannot be considered satisfactory, for, even if these errors do counterbalance, each consumer's account will still be inaccurate. It is desirable that alternating-current meters should be accurate whatever the frequency; for, if their rate of registering varies with the frequency, it would be very easy for the supply company to

cheat the consumer by using a frequency at which the meters registered too high.

2. Registration.

A meter should start registering with a very small current; one intended to carry 50 amperes should start registering with a current at least as small as half an ampere. If it requires 3 or 4 amperes to start it, and only two or three lamps are turned on in the circuit, the energy they consume will not be registered at all, and consequently the supply company will not be paid for it.

3. Absorption of Power.

The objection to the absorption of power in a meter is two-fold. It means not only the loss of a certain amount of energy, but it may mean a diminution in the voltage supplied to the lamps. A loss of 1 per cent. of the voltage means that the light given out by the lamps is decreased by from 5 to 7 per cent. The wiring of a house generally diminishes the voltage by from 1 to 2 per cent.; a meter should not increase this loss by more than 1-10th per cent.

4. Reading.

All meters should be direct-reading, and able to be read by anyone. A system of spur-wheels, dials, and pointers, similar to those employed in gas meters, is preferable to other more complicated methods of registration.

It should always be stated on one of the dials exactly what one complete revolution of the pointer on that dial means; it is insufficient and almost useless to put any numbers above the dials without stating precisely what they mean—whether one complete revolution of the pointer corresponds to that amount of energy stated above the dial, or whether the pointer moving from one division to the next corresponds to it. The above error is commonly made, but it renders the numbers of but little value.

5. Effect of Variation of Temperature.

Errors due to temperature variation may become of considerable importance, especially if copper is used for windings. Copper is, however, generally employed, as alloys having a low temperature coefficient have a much higher specific resistance than copper. It is clearly of great importance that temperature errors should be small. In some meters such errors amount to as much as 5 per cent. between the extreme ranges of temperature experienced in this country.

6. Attention.

The less attention a meter requires the better. The necessity of removing any part of the meter from the consumer's house, or even from the meter itself, is very objectionable, and should be avoided. The winding up of clockwork is another form of regular attention which it is best to avoid. A meter containing a liquid likely to freeze at any temperature to which it might ordinarily be subjected is another source of regular attention, unless a lamp or some other heat generator is placed near to prevent freezing; but this means constant of waste of energy. A meter should not contain any electric contact breakers; such contacts rapidly deteriorate with continual use, and therefore require constant attention to repair or renew.

7. Mechanical Construction.

It is essential that none of the constituent parts of a meter be liable to wear out, or get out of order, easily; extremely delicate moving mechanisms are to be avoided. A meter should be sufficiently strong for its transmission by rail without injurious effect, and should possess a water-tight and dust-tight case. A metal case is preferable to the more bulky and less durable wooden one. The case should be closed with a lock and key, or some other device, to prevent anyone tampering with the interior. The possibility of tampering with a meter from the outside, by short-circuiting, moving out of level, heating, or placing a magnet near, must also be considered. Short-circuiting from the outside of the case can be prevented by passing the mains right into the

meter and connecting there, having neither copper nor terminals exposed outside the case. Moving out of level can be prevented by securing the meter to the floor, or preferably to a wall.

8. Cost.

As has been already stated, the cost of a meter is composed of not only the initial cost of the meter, but also of what may be called the continuous cost, *i.e.*, the cost of the energy which the meter is continually absorbing. There is also a third factor to be considered, and that is the depreciation of the meter. A meter whose initial cost is very low, and which absorbs very little power, but rapidly wears out and requires constant repairing or renewing, is not really cheap. So that in considering the cost these three components must be considered.

Next to accuracy it is of the first importance that a meter shall be cheap. It is not difficult to design a very accurate and reliable meter if its cost be unlimited. What is required in practice is a meter which is at any rate *as* accurate as a gas meter, and whose cost is as little, or certainly not much more.

Classification of Meters.

Electricity supply meters may be divided into three classes—

1. Electrolysis meters.
2. Motor meters.
3. Clock meters.

Class 1.—*Electrolysis Meters.*

The most important meter belonging to this class is the one designed by *Edison*. It was the first electricity meter used in practice, and, notwithstanding the large number of meters that have been brought out since its invention, it is still employed in some places on account of its simplicity, its cheapness, and its not being at all apt to get out of order. It is a coulomb-meter, and is for use with direct currents only. The original form, as shown in the Paris Exhibition in 1881 (Fig. 1), consisted of a balanced beam, with

copper plates or cylinders suspended at each end, in a solution of copper sulphate. A current passing from one plate to the other dissolved the former and deposited copper on the latter until it got sufficiently heavy to tip over the beam. This mechanical action had a twofold effect: it registered a unit on a counting mechanism,

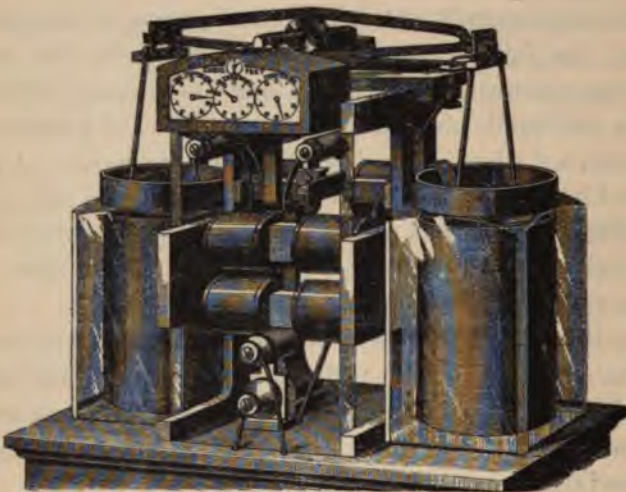

Fig. 1.—Edison Meter (original form).

and it reversed the direction of the current, so that then the heavier plate was dissolved and the lighter one had copper deposited on it, and so the process went on continually. Of course it was not possible to pass the whole current through the meter, as the resistance would be far too great, so the meter was placed as a shunt to the main circuit, and a small fraction of the current only allowed to pass through the meter. Several objections soon became apparent in this type of meter. An increase of temperature caused a larger proportion of the current to flow through the meter than formerly, for the resistance of the mains increased and the resistance of the copper sulphate decreased. The continual making and breaking of electrical contacts for the reversal of the current was found to be a great disadvantage. In the improved form of this type of meter (Fig. 2) both these objections are removed. The current always flows

in one direction; the plates have, however, to be taken away and weighed, and fresh ones inserted in the meter as they wear away.

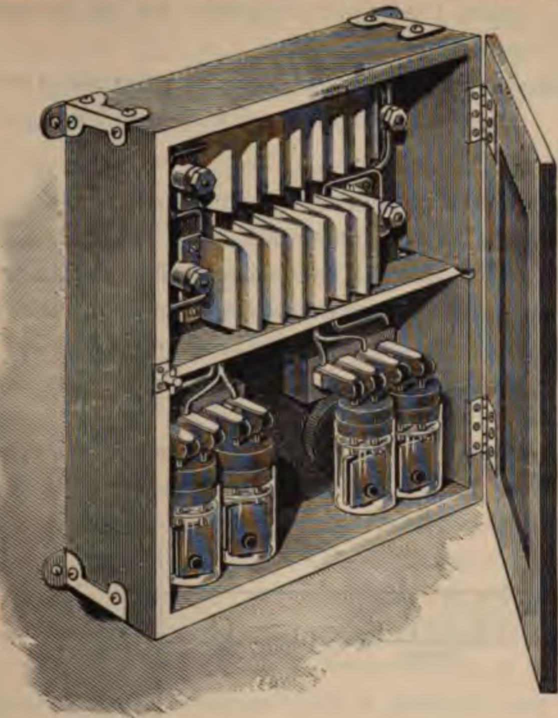

FIG. 2.—Edison Meter (latest form).

The variation of the proportion of the current flowing through the meter with temperature is eliminated by placing a copper resistance in series with the liquid of such a value that its increase of resistance due to increase of temperature equals the decrease in resistance of the liquid due to increase of temperature; the alternative path in this case being German silver. The plates are made of zinc, amalgamated to prevent local action, and they are immersed in a dilute solution of zinc sulphate. An incandescent lamp is kept burning in the meter to prevent the zinc sulphate solution freezing. The principal objections to this meter are—

1. The extremely small fraction of the total current measured by it.
2. The inability of the consumer to check his consumption

from day to day, or to ascertain for himself the amount registered by the meter, he having to rely entirely upon the supply company for the accuracy of his account.

3. The continual attention necessary; the plates having to be taken out, weighed, and fresh ones being put in about once a month.

This meter has been extensively employed in America, with very satisfactory results, though it has been but little used in this country; one exception to this being at Eastbourne previous to that system being changed to an alternating-current one.

The only other meter belonging to this class that is of sufficient practical importance to require description here is the *Lowrie-Hall* meter.

The electrolytic method is here applied to the measurement of alternating currents. An accumulator, A (Fig. 3), and an

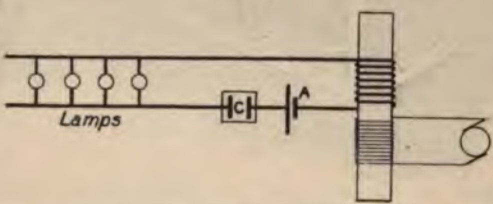

FIG. 3.—Principle of a Lowrie-Hall Meter.

electrolytic cell, C, are placed in the lamp or secondary circuit, in each house. Now there is no complete circuit through the cell and battery when all the lamps are turned off, and the conductivity of the circuit depends on the number of lamps turned on. It is relied on that an alternating current does not transfer metal from one plate to the other; hence the continuous current flowing from the accumulator is proportional to the number of lamps turned on. Consequently, the amount of metal deposited on the one plate or lost from the other is a measure of the quantity of electricity used. The whole current passes through the accumulator, but, so far from injuring it, it is even said to prevent sulphating.

This meter has not been largely used, but it has been

found to work satisfactorily in one or two cases. There are, at least, two serious objections to it:

1. If the alternating current be switched off, and any lamps be left turned on, the accumulator will discharge through them and cause a deposition of metal in the electrolytic bath.
2. The accumulator requires periodic charging, and it must not be let run down or its E.M.F. will fall considerably. Furthermore, it has been shown that an alternating current will cause a small deposition of metal, very uncertain in amount, and varying with the size and shape of the electrodes, and with the frequency.

Class 2.—Motor Meters.

This forms by far the largest class of meters, nearly all meters in use at the present time belonging to it. Before proceeding to describe the most important motor meters separately, it will be of advantage to deal with the class, for a few moments, as a whole. They one and all possess the disadvantage that they will not start registering with an extremely small current, but require a current varying from 1-10th of an ampere to 3 or 4 amperes to start them. Again, wherever there is motion, there must be friction at bearings, pivots, &c.; but in all the meters that will be described here this is either reduced to such an extent as to render it negligible, or else it is compensated for.

One of the great advantages belonging to meters of this class is that they require practically no attention; there is no clock-work to be wound up, no plates to be removed and weighed, and no cell which periodically requires charging. They are also nearly always direct-reading, or at most only require the reading on a dial to be multiplied by a constant; this latter is not necessary, and the best meters do not require it, except in the case of meters which can carry large currents.

The first motor meter of any practical value was invented by Professors Ayrton and Perry, and patented by them in 1882. The patent was, however, discontinued a few years later, owing to the apparent difficulty in overcoming mechanical friction, and to the then

small demand for electricity supply meters. The most important meters belonging to this class will now be described.

Elihu Thomson Watt-Hour Meter.

This meter is an energy-meter, and it possesses the great advantage of being able to be used with either direct or alternating currents. The field consists of two coils of thick wire, F (Fig. 4),

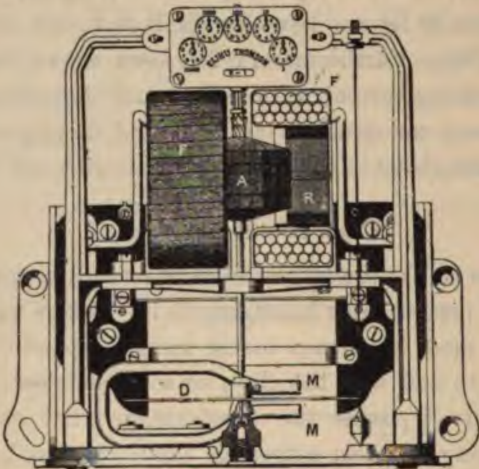

FIG. 4.—Elihu Thomson Meter.

in series, one on each side of the armature, A, and carries the main current. The armature consists of a hollow frame wound with a set of coils of fine wire on the drum principle; a small silver commutator is carried on the shaft near its upper bearing. The brushes are two light springs with silver contact pieces. The armature is in series with a high non-inductive resistance, R, carried in the back of the frame of the meter, and forms the pressure coil.

It is clear that the torque at any time is proportional to the current multiplied by the pressure at that time, and that the speed will increase indefinitely even with a constant torque, provided there is no friction or other retarding force. Now, in order that the speed may vary directly as the power, a thin copper disc, D, is fixed on the shaft, and rotated in a constant magnetic field between the poles of two or three permanent magnets, M, M. The current generated in the disc is proportional

to the speed, and hence the retardation, which is proportional to the current multiplied by the field, will also be proportional to the speed. Hence the resulting speed of the armature is proportional to the power. The mechanical friction is compensated for by taking off the pressure circuit on the lamp side of the series coils; the current in passing through these and the high non-inductive resistance to the armature produces a constant field sufficient to overcome the mechanical friction.

It is obvious that interchanging the positive and negative terminals will not alter the direction of rotation of the mechanism, for the direction of the current will be reversed in both field and armature. The direction of rotation of the mechanism can, however, be altered by interchanging the relative positions of the lamps and the generator; the direction of the current in the series coils will then be reversed, but that of the current in the armature will remain unaltered

The absorption of power in this meter is not large for an energy-meter, and it starts with a very small current: a meter of 50 amperes capacity will start with less than half an ampere.

Shallenberger Meter.

This is one of the most successful alternate-current meters existing. It is a coulomb-meter, and is so constructed that there is no electrical connection with the moving system, which consists of a thin disc of iron, D (Fig. 5), mounted on a vertical shaft, which is free to rotate. There are two coils round this disc whose magnetic axes are horizontal, and enclose an angle of about 45°. This angle can be adjusted, and upon it depends the calibration of the instrument. One of the coils, M, carries the main current; the other, C, which is composed of copper rings, is a closed coil. The main current in the former coil induces a current in the latter, which together produce a rotary magnetic field which drags the iron disc round, the action being similar to that in a two-phase motor. This motion is retarded by the friction between the air and an aluminium fan, A, attached to the shaft. The torque varies very approximately as the square of the current, and the friction as the square of the speed. Hence, when the driving

force is just balanced by the retarding force, the speed varies directly as the current. The number of revolutions of the disc is recorded by pointers and dials in the usual manner.

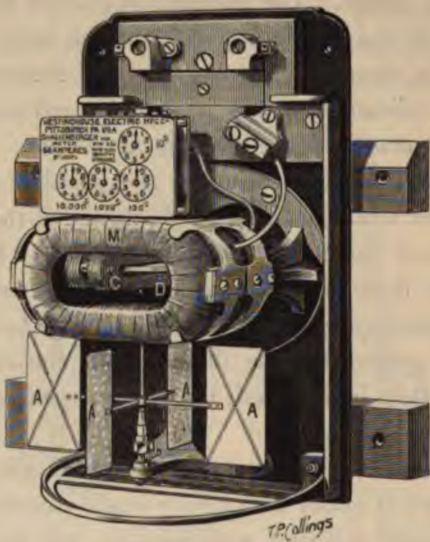

FIG. 5.—Shallenberger Meter.

A meter has recently been brought out, on the Continent, by Blathy, on somewhat the same principle as the Shallenberger meter, in that it is a two-phase motor meter; but it measures energy, and not coulombs.

Ferranti Meter.

This is also a coulomb-meter, and although its principle is applicable to both alternating and direct currents, it is very much more successful as a direct-current meter. Its action is dependent on the principle that when a current is passed through a fluid which is in a magnetic field, the fluid tends to move in a direction perpendicular to the direction of the current and to that of the magnetic field. An insulated trough of mercury, T (Fig. 6), is placed between two magnetic poles of opposite polarity. The current enters the mercury at the centre of the trough, and passes out at its rim, which forms the other terminal. In the continuous-current

instruments the magnets are excited by the current to a moderate amount, so that the magnetisation is almost exactly proportional to the current. The motion of the mercury is conveyed to a train

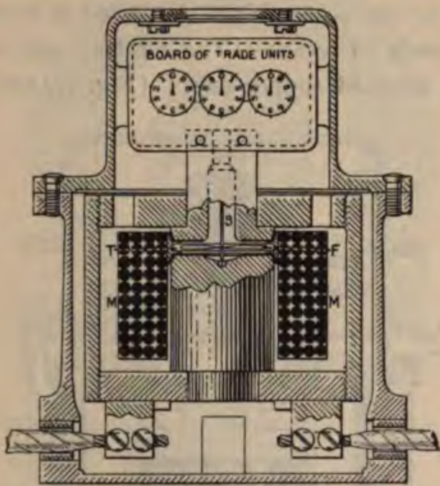

FIG. 6.—Ferranti Meter.

of recording wheels by means of a light aluminium fan, F, mounted on a vertical spindle, S, and immersed in the mercury and carried round by it. The retarding force is supplied by the friction of the mercury against the trough, and its amount depends on the speed of the mercury. The counting mechanism introduces friction which is practically independent of the speed; clearly, then, the error due to this friction diminishes in relative importance as the speed increases. To compensate for this error a fine wire shunt coil is placed across the lamp leads, thus establishing a constant magnetic force independent of the current passing through the meter. Now this force also decreases in relative importance as the speed increases. Hence the compensating force for the mechanism friction error becomes of less relative importance as the error itself becomes of less relative importance.

In the alternate-current form of this meter the magnets are laminated; it is but little used, however, as difficulties arise as to the connection between the torque and the current.

Perry Meter.

This is a direct-current coulomb-meter, and it is one of the best motor meters at present in use. Its principle depends on the fact that when a current flows through a copper cylinder from one end to the other, which is placed in a magnetic field, the cylinder tends to rotate. The rotating part of this meter consists of an inverted copper cup, C (Fig. 7), and spindle; the

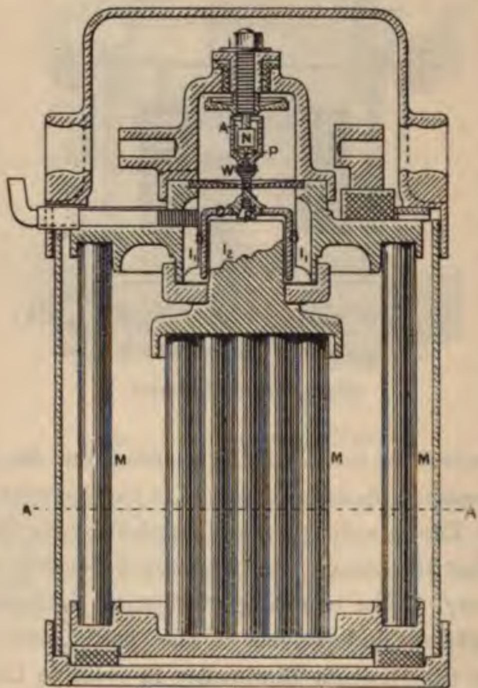

Fig. 7.—Perry Meter.

latter being fixed vertically between two pivots, so that both cup and spindle can easily rotate. The top of the spindle carries a small mercury cup, A, into which dips a nickelled rod, N, carrying P, one of the two pivots, P, P′, between which the armature or cup rotates. The whole of the copper cup is insulated with enamel except a rim at the bottom, and is immersed in mercury contained in the cylindrical space, S S, concentric with the armature. The armature moves between two

concentric iron cylinders, I_1, I_2, which form the north and south poles of a set of permanent magnets, M, M (Fig. 8), which

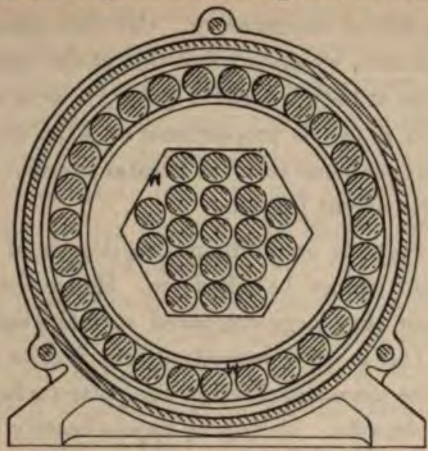

FIG. 8.—Perry Meter. Section at A A.

produce a constant intense magnetic field through the armature. The current is admitted through the mercury trough to the uninsulated rim of the armature, and flows up the sides of the cup, leaving by the nickelled rod, thus causing the cup to rotate. Pivot friction is reduced to an extremely small amount by designing the armature so that it just floats in the mercury. The speed of rotation is retarded by Foucault currents generated in the sides of the armature by having discontinuities in the polar surfaces.

A counting train is geared to a worm, W, cut on the armature spindle in order to register the number of rotations.

One of the chief advantages of this meter is the very small starting current it requires. A 60-ampere size may start with as small a current as a tenth of an ampere.

Its speed of rotation is also small, the same meter as the above revolving about $1\frac{1}{2}$ times per minute per ampere. Fluid friction is also of but little importance, as the rotating cup only moves comparatively slowly.

The law of this meter is as follows:—

Let C = Current;

F = Strength of field;

and T = Torque:

Then $T = K\,C\,F$, where K is a constant.

Frictional resistance consists of—

1. Solid friction due to friction at the pivots and friction of the skin of the mercury. Call this quantity r.
2. Fluid friction, which is a function of the speed of rotation of the armature; call it $\phi(\omega)$, if $\omega =$ angular speed. Then $\phi(\omega)$ is proportional to ω at slow speeds, and is proportional to ω^2 at greater speeds.
3. Foucault-current friction.

$\phi(\omega)$ also depends on temperature, degree of purity of the mercury, &c., and cannot be relied on. Hence the third kind of resistance is made very large compared with the resistance due to fluid friction. This is the Foucault-current friction. By properly proportioning the discontinuities on the polar surfaces this can be made very considerable. It may be approximately represented as $n\,F^2\,\omega$, where n is a constant. Hence equation of steady motion is

$$K\,F\,C = r + \phi(\omega) + n\,F^2\,\omega.$$

If r is small enough to be neglected, then $C = \frac{\phi(\omega)}{K\,F} + \frac{n\,F\,\omega}{K}$. Now, if $\phi(\omega)$ were proportional to ω, C would be proportional to ω; but if ω increases beyond a so-called critical speed, this becomes untrue. So it is necessary to make the Foucault-current friction—*i.e.*, $n\,F^2\,\omega$—as great as possible, so that when sufficiently great $C = \frac{n\,F\,\omega}{K}$; that is, the angular speed is proportional to the current.

Class 3.—Clock Meters.

The only meter belonging to this class which has achieved sufficient success to require description here is the *Aron meter*. Like motor meters, this form of meter was invented by Professors Ayrton and Perry, and included in their motor meter patent of 1882, and it also was dropped a few years later.

The Aron meter takes its name from Dr. Aron, of Berlin, who took out a patent for it in Germany some time after Professors Ayrton and Perry had done so in England. Last year, however, the Aron patent was annulled by the German courts, except in

one detail, which consisted in the placing of the two series coils in a mechanically symmetrical position to the pendulum bob. As a matter of fact, however, this is exactly what Professors Ayrton and Perry had done, though it was not stated in their patent, and the only description extant of the first specimen of this particular meter was one given in a paper read before the Institution of Electrical Engineers by Mr. Shoolbred in February, 1883; and in his diagram of the instrument he had cut away the front series coil to show the interior more clearly, leading one to believe that there was only one series coil, which obviously could not be placed symmetrically to the pendulum bob, considering its shape. There is, of course, no advantage to be gained by placing the series coils mechanically symmetrical to the pendulum bob; it is electrical symmetry that is required, and for that no patent exists.

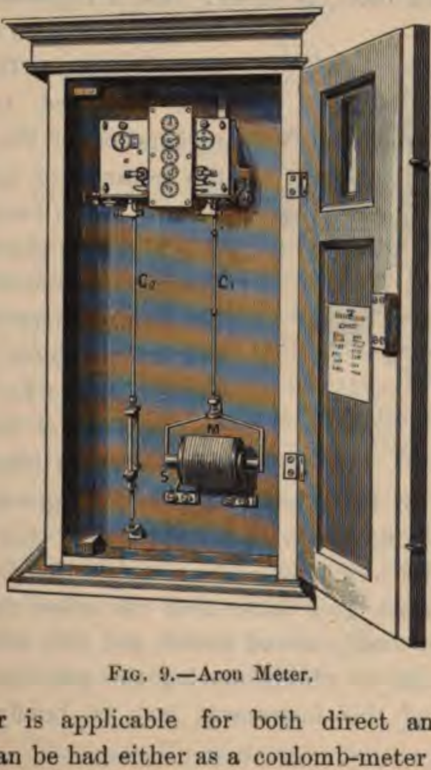

FIG. 9.—Aron Meter.

This meter is applicable for both direct and alternating currents, and can be had either as a coulomb-meter or an energy-meter, but it is chiefly used as a direct-current coulomb-meter. The

meter originally consisted of an ordinary clock, the pendulum bob being a coil wound with fine wire and placed as a shunt to the main circuit. This coil oscillated between two thick wire coils in series which carried the main current. Now, when a current was flowing, the magnetic forces caused the pendulum either to be retarded or accelerated, depending on the direction of the current, and hence the clock to lose or gain. The gain or loss of the clock then measured the energy which had passed through it. This meter has been much improved, and it now consists of two similar clocks, C_1, C_2 (Fig. 9)—one retarded or accelerated as already explained, and the other keeping correct time. Instead of having two series coils—one on each side of the shunt coil—a shunt coil, S, or permanent magnet, oscillates inside the main coil, M. The quantity registered is the loss or gain of the one clock over the other; this is registered by pointers on dials similar to those used in motor meters. The differential gear employed to effect the registration of the difference of the readings of the two clocks consists of two bevel wheels, W_1, W_2 (Fig. 10), placed parallel to one another, rotating in opposite directions with speeds respectively proportional to the rates of going of the two clocks. In between, a third bevel wheel, W_3, is placed, whose plane is at right angles to that of the other two, and it is geared to both of them. If both clocks go at the same rate, this wheel simply rotates about its own axis, and no registration is effected. If, however, one clock goes faster than the other, the whole wheel and its axis are bodily moved round, and this motion is transmitted to a train of wheels moving the pointers on the dials. The principle of this instrument may be briefly explained as follows:—

FIG. 10.—Differential Gear of an Aron Meter.

Let V = P.D. between the mains;

C = Current flowing;

T_1 = Periodic time of correct clock;

T_2 = Periodic time of retarded clock:

then $T_2 = 2\pi\sqrt{\dfrac{a}{g - \beta C V}}$

where a and β are constants, and g = gravitation forces;

also, $T_1 = 2\pi\sqrt{\dfrac{a}{g}}$.

Hence $\dfrac{T_1}{T_2} = \sqrt{\dfrac{g - \beta C V}{g}} = \left(1 - \dfrac{\beta}{g} C V\right)^{\frac{1}{2}}$.

Now it is necessary that the magnetic forces β C V shall be small compared to the gravitation forces g, in order that the meter shall register accurately. Hence, as β C V is small compared with g, $\dfrac{\beta C V}{g}$ must be small compared with unity.

$$\therefore \left(1 - \frac{\beta}{g} C V\right)^{\frac{1}{2}} = 1 - \frac{\beta}{2g} C V, \text{ very nearly;}$$

$$i.e., \frac{T_1}{T_2} = 1 - \frac{\beta}{2g} C V, \text{ very nearly;}$$

or the rate of loss of the second clock equals $\dfrac{\beta}{2g}$ C V, very approximately, which is directly proportional to C V, the electrical power passed through the meter.

Probably more direct-current coulomb-meters of this type have been made than of any other type of direct-current meters. Their range is as great as, if not greater than, that of any other meter, being about a hundredfold. They possess the great advantage of commencing to register no matter how small the current. Their one great disadvantage is the necessity of winding them up about once every month or six weeks; and it is absolutely essential that they are not overlooked, for if one clock stops not only will the meter cease to register accurately, but all previous record of energy consumed will be destroyed, and the meter may even indicate that the consumer has supplied energy to the supply company.

Intermittent Registering Meters.

There is one class of meters to which no reference has as

yet been made, namely, those which register intermittently. Perhaps the most important meter belonging to this class is that invented by Lord Kelvin.

It consists of a solenoid wound with thick wire carrying the main current, and a soft iron bar wound with very many turns of fine wire, placed as a shunt to the main circuit, so as to have the bar in a magnetically saturated condition. This bar is suspended by a spring, and when sucked into the solenoid by a current it is moved up to its initial position once every minute by a lever moved by clockwork. The amount of this upward motion is registered, and is proportional to the main current. A slot is cut in the upper part of the iron bar, so that when no current is flowing, and it is therefore not sucked into the solenoid, the lever just touches it, without moving it, at the end of its stroke, every minute. The lever is worked by means of a rotating slotted spur-wheel which is rotated by means of a falling weight. When the weight has quite run down, an electric contact is made which causes it to be instantly drawn up, and to continue causing the spur-wheel to rotate. The point of contact of the lever and the iron bar has an exactly uniform motion.

Cost of Meters.

To return to the consideration of the cost of meters.

Suppose the cost of energy absorbed by a meter be taken as low as 3d. per B.T.U., then every watt lost continuously in the meter means an expenditure of 2s. 2d. per annum; or, capitalising at 7 per cent., this means £1 10s. 11d. So that a meter whose initial cost is £20, but which absorbs practically no energy, is preferable to one costing £2 which absorbs 12 watts or more continuously.

In the case of a coulomb-meter all the energy is consumed in the main circuit coils, except when there is a high-resistance shunt circuit introduced on the lamp side of the series coils, for the purpose of producing a constant magnetic field, when this latter will absorb a small amount of energy. The consumer has to pay for the energy consumed in the main coils, and for that absorbed

in the shunt when any lamps are turned on—*i.e.*, when the meter is registering—and the supply company has to bear the cost of the energy consumed when no lamps are turned on.

The case of the coulomb-meter with the shunt circuit practically represents that of an energy-meter with the pressure coil taken off on the lamp side of the main coils. Should the pressure circuit be taken off on the generator side of the main coils, the supply company would have to bear the cost of all the energy consumed in it.

To take an example of the cost of the energy absorbed in an energy-meter whose circuit is taken off on the lamp side of the series coils.

Suppose at least one or two lamps are on for 10 hours out of every 24 hours, as is often the case in houses where there are dark passages, &c., in basements. Take the cost of energy as charged to the consumer at 8d. per B.T.U., and suppose energy costs the company 3d. per B.T.U. Let the meter absorb 12 watts in the shunt circuit continuously. Then the energy consumed in the meter in 24 hours costs the company 0·864d. Now the consumer pays for 12 watts for 10 hours in every 24, at 8d. per B.T.U., which amounts to 0·960d. So that the supply company actually gains about 0·1d. per day on the energy absorbed in this meter. Clearly under these circumstances they would much rather pay £2 for a meter which is a source of profit to them, than £20 for one which does not bring them in any profit; nevertheless, the £20 meter is really the better meter to employ, for in using it no one has got to pay for any absorbed energy.

In conclusion, I wish to express my great indebtedness to Professor Ayrton for his kindness in lending me many of these meters, and for giving me much valuable information respecting meters in general.

My thanks are also due to the Thomson-Houston Company, the Westinghouse Company, Messrs. Ferranti, and Messrs. Johnson & Phillips, for lending me specimens and diagrams of their meters.

ABSTRACTS.

M. WLADIMIR DE NIKOLAIEVE — EXPLANATION OF THE REPULSION OF ELIHU THOMSON'S RING BY THE REACTION OF MAGNETIC LINES OF FORCE: EFFECTS OF SELF-INDUCTION.

(*Journal de Physique, Vol. 4, November*, 1895, *p.* 519.)

To make this explanation clear it is necessary to employ a long iron core projecting beyond the ends of the bobbin. The magnetic flux, B, along the core will then produce a field, f, in the air, the direction of which will be at right angles to the axis of the core. The reaction between the lines f and the lines f_1 of the secondary field surrounding the ring, draw the latter to one side, f and f_1 being in opposing directions. As the field f follows the variation of the flux B, the secondary field f_1 lags behind f as much as behind B, by something between a quarter and half a period, and the resultant effect of all the reactions during a period tends to repel the ring from the bobbin. The ring under some conditions performs singular movements. If the lines f_1 of the secondary field pass through the iron, this will tend to attract the ring towards the core; and when, for example, the force is not sufficient to overcome the weight of the ring, the latter is seen to slip sideways until it touches the core.

When the ring is suspended midway between two electro-magnets the cores of which are in the same axis, the plane of the ring will then place itself parallel to the direction of the lines. This effect is due to the attraction of the lines of the primary field on the secondary field in the interior of the ring, and to an effect of repulsion outside, which results in an axial couple.

If the ring be suspended in a uniform field, the reactions of primary and secondary fields result in an equatorial couple, due to the component parallel to the axis of the bobbin, and in an axial couple due to the component perpendicular to the axis: the equatorial couple is the greater if the ring be large enough, and *vice versâ*. In order to measure the displacement of the ring, it was necessary to prevent its getting hot. The ring was immersed in water contained between two glass cylinders on which was a divided scale. In the case of small currents the ring was floated.

In Elihu Thomson's experiments the flux B passing through the ring induces a current, I, in it, which produces a secondary flux, I L, which combines with the primary flux B to make the total flux $B_2 = B_1 + I\,L$. The equation for the induction is,

$$-\frac{d\,B_1}{d\,t} = I\,B + L\frac{d\,I}{d\,t};$$

and, therefore,

$$-\frac{d\,B_1}{d\,t} = I\,B.$$

An effect of magnetic self-induction is obtained in the following experiment. A piece of iron which is strongly attracted to the magnetised core is released when a thick disc of copper is drawn along the core, the magnetising current increasing accordingly. The diminution of attraction of the iron is due to a weakening of the magnetic induction influenced by magnetic self-induction.

M. F. BEAULARD—THE SPECIFIC INDUCTIVE POWER OF GLASS

(Journal de Physique, Vol. 4, December, 1895, p. 552.)

Owing to the large electrical absorption of glass, the author found it necessary to deal with very short periods of charge. The ballistic method was employed. A condenser was charged with v volts for a very short period, θ, and discharged through a galvanometer; simultaneous readings being taken with the glass and air condensers. Corrections were made for the edge effect by the method previously employed by M. Blondlot and M. Perrot. If e is the thickness of the glass, and s its surface, B and A the respective values of the condenser with or without the glass, and E the distance between the plates; then, if $E = e - \epsilon$,

then $$K = \frac{1 + (B - B) C e}{1 - (B - A) C \epsilon}.$$

In order to vary the time of duration of the charge, either of the following two methods were employed. The first, previously adopted by M. Perrot, consists in employing the principle of the falling weight in Attwood's machine. A part of the string consists of a fine wire passing over two metal pulleys, the time of duration of charge being adjusted by moving the pulleys. The second method consists in the use of a pendulum, which during its siding cuts a capillary jet of mercury, thus making momentary connection to the condenser. The time of charge is shorter than with the first method, but always constant. In the first case the time of duration is 0·008 second, and in the second case $\theta = 0{\cdot}0004$ second.

The plates of the condenser were insulated from one another by cubes of quartz; the advantage of using this material being that its conductivity, normal to its optical axis, is small, and that its resistance does not alter with the time of electrification. The constants employed in the experiments are—

$$E = 1 \text{ cm.};\ e = 0{\cdot}682 \text{ cm.};\ \epsilon = 0{\cdot}318;\ C = \frac{4 \pi E}{S e} = 0{\cdot}022;\ C e = 0{\cdot}0151;$$

$$C \epsilon = 0{\cdot}00704.$$

Two methods were adopted for taking the measurements—firstly, by operating alternatively with the air and with the glass condensers; or, secondly, by taking a series of readings, first on the air condenser, and then on the glass condenser. In the first case, time of charge was 0·008 second, and the mean of six days' results gave $K = 5{\cdot}999$. In the second set, the mean of five readings gave $K = 6{\cdot}218$ where time of charge $= 0{\cdot}008$, and by reversing the time of charge to $0{\cdot}004$ $K = 3{\cdot}66$.

The author considers the influence of condensed moisture on the glass. Although the quartz blocks are paraffined and the air quite dry, it makes a considerable difference to the readings if the surface of the glass be damp, as will be

seen in the following table; readings having also been taken with paraffin as a check:—

Capacity of the Condenser.			Dielectric Constant.	
Air.	Glass.	Paraffin.	Glass.	Paraffin.
			K.	K_1.
404·1	498·8	462·3	7·31	1·95
394·1	480·5	450·5	6·02	1·92
410·7	510·8	463·7	8·51	1·86
406·9	499·5	465·6	6·89	1·96
413·3	514·6	472·7	8·84	1·97

As will be seen, the values of K are variable in the case of glass, and depend on the condition of the surrounding atmosphere.

The author gives a list of the constant obtained by various experiments.

V. BIERNACKI—THE RESISTANCE OF AN ELECTRIC SPARK.

(*Journal de Physique, Vol.* 4, *October*, 1895, *p.* 474.)

When a Hertzian resonator is in resonance with an exciter, the natural and forced vibrations will have the same period of vibration, and, according to M. Bjerkness's theory, their phases will be opposite in the resonator. In order that these opposite vibrations should completely die out, it is necessary that they should be damped equally, or, in other words, that the resistance of both exciter and resonator should be equal. This was experimentally confirmed by the author, by varying the resistance of the resonator until both were made equal. The exciter and resonator were identical to one another; to the two balls of the resonator was connected a resistance corresponding to the spark of the exciter. The value of the resistance which realises the condition of complete interference is, therefore, equal to the resistance of the exciter spark.

The exciter was worked from an induction coil. The resistance employed consisted of a solution of sulphate of copper, of variable density, enclosed in a glass tube 10 cm. long and 1 to 2 cm. diameter. The use of the electrolyte presents the double advantage of not altering the coefficient of self-induction of the resonator, and of not altering its resistance with any alteration of the nature of the oscillations.

The resonance was determined by the illumination of a Geissler tube, connected as a bridge across the two parallel wires of the resonator.

It was found that the tube ceased to glow when the resistance was between 300 and 800 C.G.S. units; the resistance of the spark 1 cm. long then had a resistance included between these limits. By employing a Rubens and Paalow bolometer sensitive to weak oscillations the author was enabled to measure the resistance of sparks less than 1 cm. long. The resistance was found to have increased. A spark 0·4 mm. long was found to have a resistance of between 1,200 and 1,500 C.G.S. units

The author accounts for this phenomenon by the fact that with a small distance, l, between the balls it is difficult to obtain a white, straight spark; even after cleaning the surfaces the spark is violet and irregular. With larger distances the white, straight sparks are obtained such as were employed by Hertz.

Other experiments have completely confirmed the above results. The phenomenon of the intermittent discharge discovered by Feddersen is produced through greater distances (other things being equal) than is the phenomenon of the oscillating discharge.

The unidirectional spark in the former case can be distinguished by the characteristic colours at the positive and negative poles.

By varying the distance between the balls, it is shown that the resistance increases if the symmetrical oscillating discharge changes to the unsymmetrical intermittent discharge. A Töpler-Voss machine was employed.

The phenomenon is difficult to observe with clean polished balls, but it becomes most marked when the surfaces are rough and worn. To study the influence of the nature of the surfaces, the author coated the balls with platinum black. If the distance, l, between the balls be gradually increased from a small initial value, the non-oscillating spark (first phase) becomes oscillating (second phase), and for larger values of l the spark again became non-oscillating (third phase).

In the last case the surfaces still have some influence, the spark being seen from time to time to take the longest path between the polished parts of the balls preferably to the blackened parts. It was found that the spark is oscillating under these conditions, and intermittent when passing from the blackened surface. The conclusion is then arrived at that the effect of a rough surface is to increase the resistance of the spark.

The above phenomena are explained by supposing that the resistance, R_0, of the spark not only depends on its length, represented by a term $A\,l$, but also by certain physical properties varying particularly with the condition of the surfaces, which the author represents by a term $\frac{B}{l^n}$, where B and n are positive constants.

A formula of the type, $R = A\,l + \frac{B}{l^n}$ agrees with the experimental results.

The diminution of B when passing from a rough surface to a polished surface agrees also with Mr. Paschent's results, which show that the potential difference necessary to produce a spark between two recently polished surfaces is inferior to the difference of potential necessary to produce a spark between the same surfaces previously worn by sparks.

M. PIERARD—A METHOD FOR PREVENTING THE NOISE DUE TO INDUCTION FROM ELECTRIC TRACTION IN SINGLE-LINE TELEPHONES.

(*Journal Télégraphique, Vol.* 12, *No.* 10, *p.* 218.)

Many attempts have been made to annul, or at least to diminish, the above disturbances, generally by inserting high resistances in the line circuit, these

resistances being either inductive or non-inductive. Although this method has some effect, it has the disadvantage of reducing the intensity of sound in the receivers. Where trouble is experienced from leakage currents working the annunciators at the exchange, some effect is obtained by insulating the subscribers' earth connections wherever it is likely that these may be making contact with the return rails, and also by insulating these rails from earth.

The last condition can only be obtained with difficulty, as the rails in some cases must be connected to neighbouring conductors in order to prevent the destructive effects of electrolysis.

The method suggested consists in employing a common return wire of low resistance for all the consumers. In order to completely annul the effects it is necessary that the return wire should have the same capacity and self-induction as the line wire. The diameter and lengths should be the same, and the return wire brought as near the exchange as possible. Owing to the sensitiveness of the electro-magnetic call bells now in general use, in order to prevent other bells from ringing it is necessary with this system to employ an automatic device which changes the earth return for the wire return when the receiver is unhooked.

The above solution of the problem is, however, not quite complete, for if two subscribers remove their receivers simultaneously the return wire then becomes common to both. In order to obviate a mutual disturbance, a two-way switch is supplied, which offers the alternative of using the earth return, in which case, however, the disturbances will reappear.

The above system has been in use with complete success at Brussels, and on the Liége circuit at Herstal.

The last case offered special difficulties, owing to the close proximity of an electric tramway to the telephone line.

M. COUY—THE ELECTRO-CAPILLARY PROPERTIES OF DILUTE SULPHURIC ACID.

(*Comptes Rendus, Vol.* 121, *No.* 22, *p.* 765.)

Since the author published his first notes on electro-capillarity, he has endeavoured to increase the accuracy of the measurements, in order to easily determine the function which connects the height, h, of the mercury with the difference of potential, v, existing between the mercury and the electrolyte. The method is similar to that previously employed by the author, and consists essentially in measuring the variable height of the mercury column. Corrections are made to 0·01 mm. The fall of potential produced by the current passing through the electrometer is also taken into account; this correction, however, only becomes sensible when electrolysis commences.

Very accurate observations were necessary to obtain the value of $\frac{d^2 h}{d v^2}$, which takes an important place in Mr. Lippmannt's work on this subject.

By considering the equidistant values $v - \epsilon$ and $v + \epsilon$, and the corresponding heights, h_1, h_2, and h_3, the following relation is obtained:—

$$\frac{d^2 h}{d v^2} = \frac{h_3 - h_2 - (h_2 - h_1)}{\epsilon^2}$$

A table is given stating the absolute value of $\frac{d^2 h}{d v^2}$ for sulphuric acid of different densities. The unit of potential employed was 0·1385 true volts, and the unit of length 1 millimetre; and $\epsilon = 1$, except for weak polarisation, where the rapid variation of the above value requires that the readings should be taken closer together.

The results obtained give rise to the following remarks:—

1. The maximum value of h is smaller as the solution becomes more concentrated, and cannot be measured beyond a certain point, as electrolysis sets in. The differences are notable, although lower than those given by other substances—iodides, for instance.
2. The second differential is always negative, consequently the representative curve of h presents neither point of inflection, nor tendency towards a limited value.
3. The absolute value of the second differential is not constant. A considerable increase is noticed at the end of the curve.
4. Apart from its final variation, this absolute value varies in a somewhat complex manner. Starting with strong negative polarisation where it is nearly constant, it then increases, reaches a minimum, then passes through a minimum value, to undergo a final increase. These maximum and minimum values are more marked the weaker the solution, in which case the maximum value is the greater. There is, consequently, an appreciable difference between the curves relating to dilute and concentrated solutions.
5. The measurements were made at about 17° to 18°. Variations of temperature produce small variations in h, but to what extent is not yet ascertained.

C. FAUNCE—APPLICATION OF ELECTRO-METALLURGY TO THE REFINING OF SILVER AND OTHER METALS.

(L'Éclairage Électrique, Vol. 5, No. 47, p. 369.)

After some general considerations, the author describes the results obtained with processes at present in use. The Mœbius process was invented about 10 years ago, and is largely employed in the United States and Mexico for the electrolytic separation of silver and gold.

The first installation consisted of 49 baths, designed for an output of 284 kilogrammes of silver per day; the plant was soon doubled, and has not ceased working for a single day.

The output amounts to 1,136 kilogrammes per day, although only 84 out of 98 baths are used.

The Pennsylvania Lead Company adopted the process in 1886, their object being to purify lead for the manufacture of white lead. All the ingots obtained from the Mississippi Valley contained more or less gold and silver. For the separation of these metals zinc was mixed with the lead and the whole mixture was melted. The zinc then carries the precious metals to the surface of the bath.

The resulting alloy is skimmed off and submitted to a high temperature in a closed crucible: the zinc distils, and there remains an alloy of lead, silver, and gold as a residue. This is then treated in a cupola: the lead is converted into litharge, and there remains an alloy of gold and silver.

This alloy was hitherto sent to the Assay Office in New York, where the metals were separated, at a cost of about 1·75 francs per kilogramme. This process is now carried out at the company's works, and has given rise to a very important industry. The silver is first refined in the cupola until there only remains 2 per cent. of impurity. It is then melted into plates 45 × 25·5 × 1·25 cm., weighing about 12 to 13 kilogrammes.

These plates are employed as anodes, connected by three small lugs to suitable copper rods. The 98 baths are divided up into sets of 7 in series, which form one reservoir, measuring 3·35 m. long, 61 cm. wide, and 51 cm. deep inside. The electrolyte consists of a solution of nitrate of silver and nitrate of copper in dilute nitric acid. The amount of free acid amounts to only ½ to 1 per cent. of the solution, being just sufficient to avoid the decomposition of the copper. Each bath consumes about 4 litres of acid in 24 hours. The cathodes consist of thin sheets of pure silver 33 × 51 × 0·08 cm., and weigh 1·6 kilogrammes. Four of these cathodes are suspended in each bath, alternately with three anodes, the distance between the plates being 4·5 cm. The current required for each bath is 30 amperes. All the baths are connected in series. Each anode is suspended in a muslin bag, which catches any undissolved metals in the form of a black mud, consisting chiefly of bismuth and gold, lead in the form of peroxide, and a little silver and copper. A cloth, stretched on a frame, is placed under the above arrangement of plates to collect the silver, which is detached from the cathodes by means of wooden brushes. These brushes are placed in front of the cathodes, without touching them. They receive a reciprocating motion from a small motor, and are of use not only for detaching the silver as soon as it is formed, but also for stirring up the liquid, thus keeping it of the same density and preventing polarisation. The use of the above bags and brushes is a characteristic of the Mœbius process, as is also the high current-density employed. According to the author, when 10 reservoirs—or 70 baths—are in circuit, the dynamo has to give 180 amperes at 90 volts; the resistance of the circuit being 0·5 ohm, and of each bath 0·07 ohm. The power absorbed is therefore 22 H.P. The high current-density of 195 amperes per square metre of cathode has the effect of depositing the silver in the form of crystals. The total daily output of the 70 baths amounts to 1,025 kilogrammes, and under exceptional circumstances 1,550 kilogrammes, per day. Very little attention is required for working the plant.

The silver is collected once every two days in each reservoir, and the gold once a week. An anode of the above-mentioned size is dissolved in about two and a half days.

After removal from the bath the silver is thoroughly washed with hot water, then melted in a large plumbago crucible capable of holding 56 kilogrammes of the metal.

The silver obtained has a purity of 999, and often 999·5, and with sufficient washing can be obtained practically pure. It is necessary that the anodes should

contain as few impurities as possible, such as copper or lead. The solution should be renewed as often as possible, in order to prevent its becoming too highly charged with the salts of these metals.

ANON.—ELECTRIC PLOUGHING: THE BRUTSCHKE AND SHUNPFF SYSTEM.

(L'Éclairage Électrique, Vol. 5, No. 47, p. 367.)

In the above system the plough carries an electro-motor, which gears on to a chain stretched parallel to the furrows.

The current is obtained from two cables stretched transversely at the end or middle of the field, from which two diagonal cables are connected to the electro-motor. The diagonal cables are carried on frames mounted on three wheels suitably designed to suit the irregularities of the ground. These frames, or carriers, move backward and forward over the field with the direction of the plough.

The electro-motor placed in the rocking-frame of the plough gears on the chain through an adjustable train of spur-wheels, the chain being guided by pulleys mounted at each end of the plough, and held in position by an anchor fixed at each end.

By this method is avoided the use of movable cables with capstans, with their consequent wear and tear and low efficiency, and the difficulty of employing them on sloping ground. The use of only one motor is a distinct advantage.

ANON.—THE HUTIN AND LEBLANC ELECTRIC TRAMWAY.

(L'Éclairage Électrique, Vol. 5, No. 46, p. 319.)

In this system a cable carrying an alternating current is laid along the track. This induces currents in a coil placed on the car, which is employed for working a motor. The use of a condenser is proposed for annulling effects of self-induction.

The bobbin is supported on a wooden platform, and placed as near the rails as possible.

The motor drives by means of worm-wheel gearing. For purposes of regulation the coil is wound with four circuits, each provided with its condenser and switch.

In the case of a double track the cable passes up one track and down the other. Two separate lines can also be worked from one generator. The condenser may be replaced by any other apparatus capable of developing electro-motive forces proportional to the charges which it receives from the coil, or to the quantities of electricity passing through it. The inventors suggest the use of a thermo-electric couple as a substitute for the condenser.

H. MOISSAN—ON THE PRESENCE OF SODIUM IN ALUMINIUM PREPARED BY ELECTROLYSIS.

(Comptes Rendus, Vol. 121, No. 23, p. 794.)

The difficulties arising from the use of some brands of commercial aluminium are due to differences in their chemical composition.

It has been previously found that such impurities as nitrogen and carbon are common impurities in commercial aluminium, and that their presence considerably alters its mechanical properties. In further experiments carried out on samples of aluminium obtained from the works at Praz, Neuhausen, and Pittsburg, the author has discovered an additional impurity in the form of sodium, which has a considerable influence on the lasting properties of the metal. The results of a complete analysis show that sodium impurities in some cases amount to between 0·1 and 0·3 per cent. An aluminium manufactured formerly by the firm of Bernard contained as much as 0·42 per cent. of sodium.

The author considers that the presence of sodium in commercial aluminium indicates that the electrolysis of the mixture of cryolite and aluminium gives birth to a certain number of secondary reactions in which sodium plays an important part, and depend on the composition of the bath and on the strength of the current.

When aluminium contains a small quantity of sodium, it is first attacked slowly, and afterwards with increasing intensity. If a piece of similar metal be suspended in water, it will be found coated with a very thin deposit of aluminium; the liquid then becomes alkaline, and from this moment the decomposition becomes more and more active. At every point where the aluminium contains sodium a little alkali is formed, which reacts on the metal to form an aluminate. This aluminate is then decomposed by the water, producing aluminium and sodium.

Aluminium alloys will consequently differ widely in properties according to the quantity of sodium they contain. M. Riche has shown that alloys of aluminium and tin decompose water at an ordinary temperature. The author prepared a similar alloy containing 6 per cent. of tin, and free from sodium and other impurities.

The alloy, after being subjected to great mechanical pressure, was found to have the following mechanical properties:—

	Annealed.	Hammered.
Resistance	17·6	23·43
Elasticity	8·2	22·9
Elongation	20·0	6·0

A sheet of this alloy was divided into two parts. One was placed in Seine water which was aerated every day by agitation; the other piece was placed in Seine water on the surface of which was a layer of oil several cm. thick. This was kept at a mean temperature of 20° C.

The experiment lasted two months, during which time the aluminium became covered with white patches and was pitted all over its surface, but in neither case was hydrogen liberated. The action was greatest in the case of the aerated liquid.

M. Riche has shown that decomposition of water is much more active with alloys containing a greater percentage of tin. This would then prohibit the use of an aluminium solder having tin as its chief constituent. It is essential that aluminium alloys should be perfectly homogeneous.

If distilled water be kept in an oil vessel which is not homogeneous in composition, small white spots of aluminium hydrate will be formed over its surface,

the spots being surrounded by a white ring. On removing the hydrate it is generally found that the action is produced by small particles of carbon or other substance which has set up a galvanic action. If, instead of water, a saturated solution of chloride of sodium be left in the bowl, the action becomes great enough to pierce through the metal. But if the metal be quite homogeneous, and contains no carbon, nitrogen, or sodium, there will be no chemical action, and the water remains quite pure.

Owing to the strong galvanic action set up with aluminium, this metal should obviously be used alone. It is also necessary for industrial purposes that it should be annealed.

M. D. HURMUZESCU—A NEW DETERMINATION OF THE RATIO v BETWEEN ELECTROSTATIC AND ELECTRO-MAGNETIC UNITS.

(*Comptes Rendus, Vol.* 121, *No.* 23, *p.* 815.)

Most of the methods employed for making the above determination depend on the measure of capacity and of electro-motive force, this being considered the most accurate.

Maxwell employed another method dependent on the measure of E.M.F.'s, but which was liable to errors. The author's method is similar to the latter, but free from its errors. It consists in measuring the electrostatic difference of potential at the ends of a known resistance, R, by means of a cylindrical form of absolute electrometer. To this couple is opposed that produced by an electro-dynamometer mechanically coupled to the electrometer, the system being suspended from a very delicate suspension. The value v is obtained from the two couples by the following expression:—

$$v = \mathrm{R}\sqrt{\mathrm{L}}\sqrt{\frac{0{\cdot}4342945}{4\log\frac{\mathrm{D}}{d}}}\sqrt{\frac{\frac{1}{4\pi n_1 s}}{\sqrt{1+\frac{a^2}{e^2}}}}\,.$$

By employing the cylindrical form of electrometer more accurate results are obtained, the arrangement is stable, and the adjustments are simple and accurate. By this method two constant couples oppose one another to produce small deflections. The measurement of R was made by means of an Eliott bridge after each reading.

The electro-motive force employed was 1,500 to 2,500 volts, obtained from a special dynamo.

The difference between six sets of a large number of determinations was only $\frac{1}{1300}$.

The value of v lies between $3{\cdot}0005\ 10^{10}$ and $3{,}0020\ 10^{10}$.

M. LAMOTTE—M. O. LEHMANN'S RESEARCHES ON ELECTRIC DISCHARGES IN GASES.

(*L'Éclairage Électrique, Vol.* 5, *No.* 47, *p.* 361, *No.* 48, *p.* 410, *No.* 49, *p.* 458.)

The following are the definitions employed by M. Lehmann in his research on electric discharges in gases. Every luminous discharge in a gas usually consists of four distinct parts, which are more or less developed.

1. A negative glow, formed by a very thin luminous halo surrounding the cathode, by an obscure cathodic region, and by cathode rays.
2. A positive glow touching the anode and not enclosing an obscure region.
3. A negative brush discharge distinguished from the negative glow by the separating region.
4. A positive brush discharge separated from the positive glow by an intermittent region.

According to the relative importance of the four above-mentioned phenomena, four kinds of discharges are observed—

1. The silent discharge. The positive and negative glow are produced alone; brush discharges not present.
2. The brush discharge. The positive brush is most developed, and is generally separated from the negative.
3. The trailing discharge. The negative brush is predominant, and is generally connected to the positive brush to form a luminous path.
4. The spark discharge. In this case the above are combined into one path, which crosses the obscure cathodic region.

When the discharge is very intense it may become disruptive, this taking place even within the electrodes, which causes the metal to disintegrate. The brush discharge which is formed carries metallic vapours.

The variable factors which are capable of influencing the nature of the discharge are as follows:—

1. The intensity of the discharge, depending on the quantity of electricity brought into motion, on the difference of potential, &c.
2. The pressure of the gas.
3. The distance between the electrodes.
4. The shape and number of these electrodes.
5. The shape of the vessel containing the electrodes.
6. The chemical nature of the gas and of the electrodes.
7. The temperature.
8. The proximity of electrified bodies.
9. The proximity of magnetic bodies.
10. Currents in the interior of the gaseous mass.

These researches were carried out with an influence machine driven from a small gas engine. To vary the voltage through the necessary limits resistances were introduced in the circuit, these consisting of columns of such non-conducting liquids as alcohol, ether, or essence of turpentine. These were, however, eventually replaced by a spark micrometer. When the latter is placed in circuit the charges accumulate until the potential difference between the two poles has reached a certain value, at which moment a violent discharge takes place.

In order to study the influence of the shape of the containing vessel, Mr. Lehmann constructed a form of Leyden jar without coatings, consisting of a glass globe of about 1 litre capacity, sealed hermetically, and with an electrode passing into it. This could be charged in the same way as a Leyden jar. If the extremity of the electrode be pointed, the discharge takes place spontaneously from the point, and during several seconds the bottle remains phosphorescent.

Experiments show that the quantities of electricity accumulated on the glass in the neighbourhood of the electrodes have a large influence on the phenomena in question.

The action can be diminished by making the distance from the glass as great as possible relatively to the distance between the electrodes. The presence of the micrometer in the circuit has not only the effect of increasing or diminishing the strength of the discharge current, but also of producing a difference in these values at the anode and cathode, on account of its effect in retarding the flow of electricity to the electrode connected directly to the machine.

This difference in the intensity is explained by the fact that the two parts of the discharge do not take place simultaneously. The intensity is the quantity of electricity which discharges during unit time at any given moment, and cannot be determined by taking a mean with respect to any given time. The intensity is not represented by

$$\frac{1}{\tau}\int_t^{t+\tau} \frac{dQ}{dt}, \quad \text{but by} \quad \frac{dQ}{dt}.$$

The influence of the intensity on the nature of the discharge is determined by a simple law. It is found that there is not a clear distinction between the silent discharge and brush discharge, and neither is there between the silent and trailing discharge. It has also been found that there is no difference in colour between the positive and negative light, as was hitherto thought by many.

With respect to the influence of pressure, it is found that as this decreases so the luminous effects disperse.

When the pressure is diminished the silent discharge tends to change to a trailing discharge, and, with an increase of pressure, to a brush discharge. The spark discharge completely crosses the obscure cathode region, and pressure has little influence on its shape; its length increases with the rarefaction of the gas.

Increasing the distance between the electrodes has the effect of increasing the length of the brush discharge if the intensity be increased simultaneously with the distance traversed. If the electrodes be approached the positive and negative glows combine to form one luminous region; as is also the case with the two brush discharges. With regard to the shape of the electrodes, the trailing discharge is formed with greater difficulty when the cathode is blunt; as is also the case with a brush discharge from a blunt anode. Experiments show that the blunting of an electrode has the effect of diminishing the intensity.

If the discharge takes place between a positive plate and a negative point, the positive glow appears to adhere to the plate, the effect being reversed with reversed poles; this takes plaee specially with small distances and small pressures.

With large pressures and distances it is found that pointing an electrode has the effect of hindering the formation of a spark, especially in the case of the negative electrode. When one electrode is earthed, luminous effects appear only at the insulated electrode. With respect to the influence of external conditions, it is found that intense discharges may take place through capillary tubes when the potential has reached a high enough value. In free air, or in vessels whose dimensions are very great with respect to the distance between the electrodes, only faint

brush or trailing discharges are formed. The strongest discharges take place in small vessels.

In the case of electrodes consisting of several points, the discharge takes place from one point only, changing from one to the other. If the electrodes be distributed in different parts of the vessel, the discharge takes place between two neighbouring ones, changing from one couple to the next.

The presence of neighbouring electrified bodies has no appreciable influence on the discharge.

The effect produced by neighbouring magnetic bodies is well known. The more rarefied the air, the greater is the deviation of the discharge; the effect is inappreciable in the case of a spark, or with ordinary pressures.

An increase in the temperature has the effect of favouring the discharge, owing to convection. Luminous discharges passing through compound gases decompose them with great rapidity. With respect to the influence of internal currents in the gas, these under ordinary conditions have no effect on the long and brilliant sparks produced by a machine; the time of duration is too short. Mr. Lehmann found that under a pressure of 5 to 8 atmospheres the spark could be interrupted by directing a current of air quite close to the surface of the positive electrode, but at the cathode the current of air had no effect, and would not even deviate the spark to any appreciable extent. These phenomena are modified with a current of hot air, as is shown by the following experiment.

In the case of a ball as positive electrode and a point as negative electrode, the spark is extinguished, and replaced by a silent discharge. By directing the current of hot air on the point the metallic vapours are drawn out in the shape of a long yellowish flame.

Taking as positive electrode some glowing charcoal, and a small brass ball as negative electrode, no spark can be produced by an influence machine; but a silent discharge takes place, igniting the charcoal in the same manner as a current of air. On reversing the poles long zigzag sparks are produced.

With respect to the electrification of air by friction, MM. Elster and Geitel have shown that gases can become positively electrified by friction against solid bodies.

Mr. Lehmann considers that the spontaneous electrification of air, and consequently the want of symmetry existing in the discharge between two poles, is to be attributed to the presence of an obscure discharge preceding the luminous phenomenon. An increase of temperature rapidly increases the intensity of this discharge, and consequently the luminous discharge is produced at the cathode before the difference of potential limit is attained at the other points of interruption. In very rarefied gases the obscure cathode region offers so great a resistance to the discharge, that the latter takes place over the surfaces of the vessel; the charge is formed at the anode, and then discharges to the cathode, but the two phenomena take place so rapidly that it would be impossible to measure the oscillations of potential by ordinary methods.

The discharge from the cathode to the walls of the vessel would explain the shadow projected on the latter by bodies placed between them and the cathode. Mr. Lehmann attributes the greenish fluorescence of the glass to these phenomena.

The stratifications are accounted for by the electrified air being accumulated in too great a quantity; the electricity produced by the machine is not sufficient to push the brush discharge to the anode, the luminous discharge stops, and a new luminous region is formed, until the discharge is again started and the obstacle overcome.

Mr. Lehmann proposed to determine the potential difference of the discharge by placing an exhausted tube in the electrostatic field produced by a spherical conductor, and of which the intensity at every point could be calculated. The field would be varied until the tube commenced to glow. This method is rendered difficult owing to several causes, but chiefly owing to moisture.

It was found that new tubes refuse to light up except with very high tensions, much above those eventually necessary to excite them; the reason for this is not yet known.

According to Mr. Lehmann, the discharge is always intermittent, and must necessarily be so, as it takes place more rapidly in gas than does the displacement of electricity in the best conductors.

Heat and light are chiefly produced in the positive or negative glow because at this point is produced the disruptive discharge which absorbs the greatest portion of the electrical energy.

F. KOLACEK—THE AXIAL NATURE OF MAGNETIC LINES OF FORCE DEDUCED FROM THE PRESENCE OF THE HALL PHENOMENON.

(L'Éclairage Électrique, Vol. 5, No. 49, p. 475.)

The work of Maxwell and Hertz has shown that there exists the following relation between electric and magnetic forces:—If the electric force varies, this gives rise to a magnetic force in the plane at right angles to its direction. The work produced by the latter along a very small contour is proportional to the area limited by the contour. This relation is only correct in perfectly insulating and isotropic mediums. If the electrostatic field be sufficiently strong, a spark will be formed; this has, however, not been noticed in the case of a magnetic field.

Recent theories explain this difference by supposing that magnetic phenomena consist of movements of rotation round the line of force as an axis, this explanation being further corroborated by the existence of rotatory magnetic polarisation, and also by that of the Hall phenomenon.

If a constant current be sent through a gold leaf, and a sensitive galvanometer connected to two such points that no deflection is produced, and if a strong and uniform magnetic field be then established normally to the plan of the leaf, the galvanometer produces a deflection, which is reversed if either the direction of the current or the polarity of the magnet be reversed.

The author establishes three hypotheses—

1. The primitive current and the Hall current are merely directions, or, in other words, all the phenomena take place in the sense of their lengths. If a magnetic line of force be set up at right angles to the

plan of the leaf, and if this line is also a simple direction, the Hall phenomenon becomes an impossibility, for, on account of symmetry, the current could be produced in one direction as well as in the other.

2. If the two currents be considered as axes—that is to say, as giving rise to phenomena corresponding to a rotation around their direction—the primary current will be characterised by a certain property taking place on the lower face of the leaf. If the magnetic line of force be a simple direction, the two directions characteristic of the Hall phenomenon will again be equivalent, and the phenomenon again becomes impossible.
3. If the electric current possesses both the properties of a direction and of an axis, and if the line of force be only a direction, the Hall phenomenon should not change sense when the field was reversed.

These objections can only be overcome by attributing the properties of an axis to the lines of force—the conclusion which was arrived at by M. Curie.

ANON.—ELECTRIC TRACTION IN HAMBURG.

(Elektrotechnische Zeitschrift, 1895, *No.* 40, *p.* 637.)

The system of electric traction in Hamburg is now the largest in Europe. When the enterprise was started a part of Hamburg was dealt with, and the contract placed in the hands of the Union Company of Berlin, who adopted the Thomson-Houston overhead trolley system for three of the lines. The inauguration took place in spring, 1894, and eight lines have been in operation since May, 1895. The total length of the track is more than 200 kilometres, exclusive of junctions, &c.

The whole network is divided into nine sections, each of which is worked independently by feeders, consisting of iron-armoured lead-covered cables of the Felten & Guilleaume type, and buried to a depth of ½ to 1 metre under the footpath or pavement, in compliance with special rules.

The necessary power for the working of the line is supplied by the municipal central station, erected in the first place chiefly for lighting purposes. It tontains three Schuchau triple compound steam engines, each of 600 H.P., direct-coupled to three Schuckert dynamos of 240 volts, 1,700 amperes capacity at 120 revolutions per minute. As the motors work at 500 volts, three direct-current transformers are employed. In view of the large demand three additional Schuckert dynamos have since been installed—two for lighting, and the third for the street trams—working at 450 to 600 volts. Three sub-stations each contain a transformer of 150 amperes capacity, which are capable of supplying current in case of need to a temporary feeding point in the Wilhelmstrasse. As the increasing demand soon took up the full available load of the above station, it was decided to erect a second station of 3,600 H.P., destined mainly to provide current for traction purposes only, whilst the present station will chiefly be employed for electric lighting.

The overhead trolley wire consists of hard-drawn polished copper wire, 53 sq. mm. section, supported at a height of 6 metres over the centre of the track, and

is divided into sections of about 500 metres, rendered electrically independent of one another by so-called section insulators in the form of switches, which are generally closed, and thus form an uninterrupted conductor from the feeding points to the cars. The police and fire brigade authorities are in possession of the keys of the switch-boxes, which enables them in case of need to cut out any faulty section.

The supporting posts consist of steel tubes of different diameters shrunk together, and to which ornamental electric light brackets are sometimes fixed In some cases the posts carry double brackets for supporting two trolley wires. In narrow streets posts are avoided, the trolley wires being suspended from brackets fixed to the houses. Over the Lombardsbrücke the trolley wires are supported by means of steel wires. As a protection against falling telephone wires, in some places the trolley wires are protected by wooden mouldings.

Lightning conductors of the Thomson magnetic type are placed in boxes fixed to the posts.

Every car is provided with a lightning protector. The cars weigh 6,680 kilogrammes. The length is 7·75 metres; width of seat, 0·5 metre; and accommodates 20 seated passengers and 10 standing, including conductor and driver.

Each car is fitted with five incandescent lamps connected in series.

The driver works the alarm bell with his foot, the hands being thus free for manipulating brake or starting gear. The starting resistance has six steps.

The contract for the electrical part of the cars was entrusted to the Union Company of Berlin.

The cars have two axles, the centres of which are 1·7 metres apart, the wheels being 0·75 metre diameter. The car and lower frame are quite independent of one another; the weight of the former being taken by four helical springs.

On one of the axles is mounted the G.E. four-pole motor, which hangs from an elastic suspension, and which thus relieves the axle from the weight of the motor and frees the latter from sudden jolts. The total weight of the motor is 810 kilogrammes, including gearing.

Its output is 20 H.P. normal and 30 H.P. maximum; its speed is 525 revolutions per minute when the velocity is 16 kilometres per hour. The motor is fitted with single reduction gear having a ratio of 4·78 = 1, and running in an oil box. The average speed, including stoppages, is 12 kilometres per hour; this is not lessened with the addition of an extra carriage. Since the commencement 240 motor cars and as many additional cars have been in use, and which can be increased to 400 of each kind.

Phœnix rails are employed, 15 cm. high, having 45 kilogrammes weight per metre run. To form the return conductor, the rails are bonded together with bare copper wire.

The steepest gradient is 5 per cent. The working hours are from 6.30 a.m. to 1 a.m., during which time the consumption is 10,000 kilowatt-hours. 300 men are employed.

The following is a comparison between the results of electric and horse traction previously in use :—

	Electricity		Horse Traction.
Number of motor cars per day	14–22	...	14
Working hours	16	...	15·5
Distance travelled per day	155	...	130
Total passengers carried per day... ...	12,970	...	9,335
Income per car kilometre, in pfennigs ...	58	...	43·6

The cost of working per car kilometre amounts to 7·68 pfennigs, and for the additional carriages 1·43 pfennigs; the whole working expense amounting to 4 pfennigs less than the contractors had guaranteed. The cost of cleaning and repairs amounted to 1·5 pfennigs per car mile.

W. H. JULIUS—A DEVICE FOR PROTECTING MEASURING INSTRUMENTS AGAINST TERRESTRIAL VIBRATIONS.

(*Elektrotechnische Zeitschrift*, 1895, *No.* 45, *p.* 717.)

This device consists of a lower foundation plate in the form of an equilateral triangle, and a circular plate carried on three parallel rods fixed to the three corners of the triangular plate. These two plates are also connected in the centre by a rod, along which a weight of 3 or 4 kilogrammes can be displaced by means of a rack and pinion. Each of the above rods is provided with a bracket projecting outwards, and from which the support is suspended by means of steel wires 2 to 3 metres long. These wires lie vertically, and are fixed at their upper ends. The instrument is placed on the supporting table, and in such a position that its centre of gravity lies in the axis of the whole arrangement. The weight is moved along the arm until the centre of gravity of the whole suspended system lies in the plane of the three points of suspension.

To the above brackets are fixed brass wires carrying metal vanes dipping into a liquid, thus acting as a damping arrangement against the swinging of the system. The author states that the above method has given very satisfactory results.

OSCAR VON MILLAR—THE ISAR WORKS.

(*Elektrotechnishe Zeitschrift*, 1895, *No.* 45, *p.* 700.)

A water-power station was erected on the Isar, some distance from Munich, for the purpose of supplying electric light and power to this city.

The dam wall is 100 metres long, and is built of Portland cement. The first plant is installed at a distance of 800 metres below the weir. Four turbines are employed. The available fall amounts to 3·6 metres, and the normal quantity of water to 50 cubic metres per second; 2,000 H.P. are therefore available under these conditions, and in the worst case the power falls to 1,500 H.P. It has been arranged that a second and third plant, each of 2,000 H.P., can be connected together, thus raising the total available power of the Isar works to 6,000 H.P.

Both the mechanical and electrical plant at present in use is capable of supplying 1,000 H.P. The machines in the first station consist of two Jonval turbines, each of 500 H.P.

Automatic governors could not be employed for regulating the speed of the

turbines, owing to too great variation of the water level. There is used instead a special automatic device, consisting of a resistance, which serves to load up the machines at periods when there are few lamps on circuit, and when the use of motors would cause fluctuations in the light.

The dynamos and transformers, working on the three-phase system, were supplied by Brown, Boveri, & Co. The dynamos receive their power from the turbines by simple toothed wheel gearing, and are capable of delivering 350 kilowatts at 105 revolutions and 5,000 volts pressure.

Out of the 350 kilowatts 66 per cent. is taken up by electro-motors, the resulting lag producing a ratio of 1 : 1·2 between the real and apparent watts. The distance of transmission is 15 kilometres. No special attention was paid to automatic regulation, as the drop in pressure amounts to only 5 per cent. In some cases large motors used by some of the mills were run from special machines in order not to interfere with the lighting plant. The transmission wires consist of 8 mm. diameter copper wires, supported on three-mantle porcelain insulators fixed to wooden poles.

The transformers have a reduction ratio of 5,000–110 volts. Single transformers are employed for the large motors. For the purposes of lighting, sub-station transformers are used, these sub-stations containing switches and fuses for the high- and low-tension conductors.

The low-tension conductors consist of a closed network passing through most of the streets; but in such places where large motors are not required only two conductors are laid, these being connected to one of the three phases.

For small motors, monophase as well as three-phase motors are used.

Current is supplied from these works at a sliding scale, regulated according to the probable duration of use of groups of lamps and motors, and which amounts to about 2·5 pfennigs per 16-C.P.-hour, and to about 10 pfennigs per H.P.-hour.

A reduction of these rates is made for large consumers. The adoption of such a tariff is recommended for water-power installations in which the working expenses are independent of the duration of the use of lamps and motors. The cost and inconvenience of the use of motors is thus done away with. Consumers are acquainted beforehand as to the probable amount of their expense. Meters are, however, supplied to consumers if desired. Although the Isar works are only supplying a small part of Munich, their load is taken up by 2,500 16-C.P. lamps, 30 ¼-H.P. electro-motors, and two 25-H.P. motors.

E. LOHR.—THE MIDDLE CONDUCTOR IN THE THREE-WIRE SYSTEM.

(Elektrotechnische Zeitschrift, 1895, No. 48, p. 753.)

If the middle conductor in a three-wire system be loaded, this causes a drop in pressure on the heavier loaded side of the system, and a gain in pressure on the other side. If, therefore, the drop in pressure on the weaker loaded outer conductor is less than in the middle conductor, then the pressure on the lamps on this side will be higher than that of the machine.

In order to minimise these effects, the section of the middle conductor should be calculated with some care.

The difference in the load on the two sides of such a system amounts to between 2 and 10 per cent. under normal conditions.

The author considers the case of a network having a maximum current capacity of 10,000 amperes. All the conductors are assumed to be bunched up into three conductors, reaching from the central station to the central point of the network. The distance amounts to 1,200 metres, and the drop of pressure in the outer conductors to 20 volts. The cross section then works out to 5,260 square mm.

With a difference of load of 2½ per cent., or 250 amperes, there is produced a drop of 2 volts on the middle conductor, with a cross section of 2,630 square mm., or half the cross section of the outer conductor.

If such sections were employed in practice the above drop would not be quite realised, and would be somewhat greater than 20 volts, owing to the increase in temperature. A specific resistance of $\frac{1}{57}$ at 15° C. was assumed in the above case. The author has measured the specific resistance under working conditions, and found this to amount to $\frac{1}{51}$ to $\frac{1}{53}$. These were for cables of 725 square mm. section carrying 610 amperes, 500 square mm. carrying 500 amperes, and 50 square mm. carrying 90 amperes.

In the above example the drop of pressure would be—

$$\frac{1,200 \times 4,875}{52 \times 5,260} - 2 = 19{\cdot}4 \text{ volts, and } \frac{1.200 \times 5,125}{52 \times 5,260} + 2 = 24{\cdot}6 \text{ volts.}$$

The difference in the pressure of the machines then amounts to 5 volts, and is consequently 4½ volts higher than would be expected.

It is next considered whether the middle conductor is capable of generally maintaining the pressure of the network in the case of a one-sided earth leakage.

In an underground system such as in the case mentioned above, the leakage on one side would not exceed 1,000 amperes. The loss in pressure produced by the overloading of one side will then amount to 35 volts on one side, and 14 volts on the other side. One machine then must give 15 volts more, and the other 6 volts less, than corresponds to the normal pressure.

It is recommended to lay two neutral cables from the central station, especially when these are insulated. A fault in the neutral conductor may cause a serious interruption to the working of the system. Where several feeders are laid together it is advisable to place all positives on one side, all negatives on the other, and the neutrals in the centre.

It is advisable to connect the middle conductor to earth, both at the central station and at several points on the network.

Fuses should not be used in the neutral conductor.

In the case of a bare middle conductor special precautions should be taken against oxidisation due to damp earth, and against electrolytic action. The effect due to the former cause was found by the author, after three years' experience, not to be serious. The drop is minimised by a judicious disposition of the neutral feeder. This should be run radially from the central station to the different points. Ample allowance should be made in the section of the distributing main. A greater allowance should be made in the case of bare middle conductors than with insulated ones. It is advisable not to connect between the middle conductor and

the armouring of the outers, as such connections are difficult to carry out in an efficient manner.

In spite of the somewhat increased section in the case of the bare middle conductor, there is still to be found an economy over the insulated conductor, especially with the junction boxes, through which there is no necessity to pass the middle conductor.

The connections on the bare conductor are best soldered, and the joint protected with insulating sockets.

In the case of house installations it is advisable to employ equal section of copper and the same amount of insulation on all three conductors.

ANON.—THE GESUNDBRUNNEN-PANKOW ELECTRIC TRAMWAY.

(*Elektrotechnishe Zeitschrift*, *No.* 44, 1895, *p.* 687.)

This line commenced operations on 10th September, 1895. The length of the double track amounts to 3·4 kilometres, of which 0·9 kilometre lies in the Berlin territory.

The contract was carried out by Messrs. Siemens & Halske, who commenced the line in April, 1893, and to whom a 50 years' concession has been granted After some discussion with the Berlin authorities, their consent was obtained in November, 1894, for the the use of an overhead trolley system.

The slopes are very gradual, and the smallest radius is 25 metres. The trolley wire, consisting of hard-drawn copper wire 8 mm. diameter, is suspended at a height of exactly 5 metres over the track, partly by means of supporting wires fixed to poles on each side of the road, and partly to brackets fixed to poles. The posts are of steel, on the Mannesmann system, with ornamented cast-iron bases fixed in concrete foundations. In many cases the trolley wire is fixed to a strained steel wire fixed and insulated at each end to a curved bracket. This offers a neat appearance, and gives elasticity, and reduces the wear of the trolley wire. This system also offers the advantage that the latter cán be adjusted. Instead of the ordinary trolley wheel the Siemens & Halske trolley frame is employed, the chief advantage of which is that no special system of connections is necessary at the shunts and crossings, as the frame is wide enough to bridge from one trolley wire to the other.

The motor cars, of which there are eight at present in use, each contain a 25-H.P. four-pole motor. The mechanical transmission takes place by means of single reduction gearing, the ratio of which is 1 : 5. The small wheel is made of bronze, and the large one of steel; these run in an oil box.

The average velocity amounts to 17·5 kilometres, and can be increased to 25 kilometres per hour. Each of the cars holds 30 passengers.

At the power station, the boiler house contains two tubular boilers of the Simonis & Lanz type, having 75 square metres heating surface, and working at 10 atmospheres pressure. Both steam engines are of the horizontal condensing type, each having an output of 110 H.P. at 135 revolutions, and direct-coupled to 70-kilowatt dynamos. These are of the inner-pole type, with eight poles, working at 500 volts.

The line has a 5-minute service on Sundays and holidays, and a 10-minute service on week-days.

W. KLUG—THE ELECTRIC LIGHTING OF THE CENTRAL RAILWAY STATION OF MUNICH.

(*Elektrotechnische Zeitschrift*, 1895, *No.* 49, *p.* 761.)

In the system decided upon for the above installation the arc lamps were to be worked by continuous currents for the outer part of the station, and alternating currents were to be used for both arc and incandescent lamps within the station buildings. The greatest distance was 4·3 kilometres. The contract was placed with Messrs. Siemens & Halske.

The three engines, by Messrs. J. A. Maffei, of Munich, are of the horizontal compound condensing type. Their output is 130 nominal H.P. normal, 140 H.P. maximum, at 8½ atmospheres pressure. The three boilers have each a heating surface of 130 square metres, and a working pressure of 9 atmospheres. Two surface condensers are used, capable of condensing 400 kilogrammes of steam per hour.

The above engines drive by belt a continuous-current dynamo and alternator, coupled together on one bed-plate. If necessary, the belt can be removed, and the alternator run as a motor. The machines can also be separated in case of breakdown. They are coupled together by means of a Raffard elastic coupling, which also serves as pulley. The three alternators have each an output of 51,000 watts at 2,000 volts; the three continuous-current dynamos have each an output of 35,000 watts at 330 volts. The latter machines supply the necessary exciting current for the alternators. These machines run at 428 revolutions per minute. One set is kept in reserve. The alternators are provided with a third winding, so that they can be employed at some future date as rotatory field motors for driving the continuous-current dynamos; alternating current being obtained from the Isar water-power station.

The alternators have 14 poles, the frequency being 50. The temperature rise of the iron and copper after 16 hours' run at full load amounts to 40° C. above the surrounding atmosphere.

The alternators have auxiliary low-pressure windings, by means of which their voltage can be measured, and the use of switch-board transformers thus avoided.

The three sets of machines are insulated from earth by impregnated wooden beams fixed under their foundations. To further reduce the danger from shocks to the attendants, the iron parts of the machines are connected together by means of an insulated copper wire through an inductive resistance consisting of a small low-pressure transformer placed in oil and connected to earth. A bell, connected on the secondary of this transformer, informs the attendant when any connection is made between the machines and earth. This method also serves as an efficient lightning protector. Two switch-boards are employed for the alternating and continuous currents respectively. All fuses are placed behind the switch-boards, in order to minimise personal dangers. The whole output of the machines is measured by ampere-hour meters.

The machines are put in parallel by observing when their voltages are equal and in opposition, as shown by a voltmeter and an incandescent lamp; the latter serving as a guide for the engine-driver.

From the station are run two high-pressure conductors and nine continuous-current circuits. Branches are made at suitable places on the high-tension conductors for the working of the transformers. These are placed outside the buildings in small brick sheds, and their sizes vary from 2·5 to 20 kilowatts, their ratio of transformation being from 2,000–120 volts. In most cases their secondaries are connected to ring mains.

Switch-boards are fixed in the transformer sheds, on which provision is made for disconnecting both high- and low-pressure conductors from the transformer, and for connecting any transformer to the ring main. Band arc lamps are used, and the 16-ampere lamps burn for 18 hours.

The continuous-current lamps are carried on lattice masts 12 to 18 metres high. The overhead conductors are of bare copper wire carried on three-mantle insulators. Covered conductors are used for the branch circuits, and for such parts of the conductors as lie near telegraph wires. The minimum distance between the high-tension conductors and the rails is 7 metres. Ordinary telegraph insulators are employed for the low-tension conductors.

Lightning protectors and fuses are supplied on all the circuits.

The total number of lamps employed is 1,114 incandescent lamps, 76 9-ampere arc lamps, 6 12-ampere arc lamps, and an extension of 173 incandescent lamps.

E. KOLBEN—SOME CHARACTERISTICS OF SYNCHRONOUS MOTORS.

(*Elektrotechnische Zeitschrift*, 1895, *No.* 51, *p.* 802.)

Many investigations have been made with reference to synchronous alternating-current motors, but few results have been published as to the practical capabilities of these machines.

Mordey has characterised in the now well-known *v* curve the working conditions of the synchronous motors under variable excitation.

More practical results are obtained by employing three-phase synchronous motors.

The author gives curves of a three-phase synchronous motor working at different loads. A curve is also given showing the true watts absorbed at different points on the *v* curve. It is noticed that the minimum armature current for almost all loads, and with a constant primary pressure, corresponds to an almost constant exciting power. It is therefore unnecessary to vary the excitation, even through very wide limits of load. The efficiency of the motor remains the same through wide limits of excitation. It is, however, only well-designed synchronous motors which possess this quality, *i.e.*, only those having low self-induction and small drop. In motors with a large armature reaction the watt consumption increases on account of the back field produced by the increased current, which sets up eddy-currents in the pole-pieces of the magnets.

This effect is most marked in the curves of a good and a bad machine; the

armature current on short circuit being plotted with a varying excitation. The watts in one case are made up of C^2R and hysteresis losses. In the bad machine, however, eddy-currents predominate, and the curve has the shape of an eddy-current curve; the former curve, however, resembles the well-known hysteresis curve.

The *v* curve at light load and the values of the current on short circuit, form a reliable indication as to the qualities of the machine as a motor or as a generator. The steeper the slope of the two arms, the better is the machine suited for running as a motor, specially with regard to falling out of step by overloading; and as a generator, with regard to drop on inductive loads.

According to Mr. Swinburne, only motors with such characteristics can be employed with advantage as phase-rectifiers, which are used for raising the power-factor and reducing the inductive drop of a system.

The relation of the current on short circuit to the excitation forms a very important point in the behaviour of synchronous motors. An insensitive synchronous motor which bears overloading has generally a weak armature field, and consequently a short-circuit characteristic which rises quickly for a small variation in the excitation.

It may be stated as an approximate rule that a machine is satisfactory if on short circuit its normal current is obtained with an excitation which on open circuit would produce one-third of the normal pressure. By means of these short-circuit curves it is also possible to ascertain the drop of the machine working as generator on inductive load.

The form of the E.M.F. curve bears some importance on the behaviour of synchronous motors. If both machines be of the same construction, and have, consequently, similar curves, then the minimum current taken by the motor under the most favourable conditions of excitation will be the same at all loads. If, on the other hand, the two machines are of different construction, one giving a sine curve and the other a distorted curve, this will have the effect of reducing the power-factor and of raising the apex of the *v* curve for different loads, on account of the currents which circulate between the two machines to equalise the pressure curves.

v curves are given showing the behaviour of the above motor with different curve forms for the generator. Illustrations are also given of the general arrangement of a 60-H.P. three-phase motor for 3,000 volts, and also of a three-phase 300-H.P. 5,000-volt motor, both built at the Oerlikon Works. The machines have both stationary field and armature windings, and on account of the favourable design of the field magnets cannot be pulled out of step. The efficiency was found to be high.

Dr. T. BRUGER — MOTOR METERS, WITH SPECIAL REFERENCE TO THOSE OF MESSRS. HARTMANN & BRAUN; ALTERNATING-CURRENT MOTOR METERS.

(*Elektrotechnische Zeitschrift*, 1895, *No.* 43, *p.* 676.)

The author draws attention to the errors which may arise in certain continuous-current motor meters owing to the alteration in the nature of the

contacts which admit current to the revolving armature. This is, however, not the case with alternating-current meters, as inductive effects give a means of producing rotation without the necessity of admitting current to the armature.

The principle under which such meters work may be represented by the expression, $K = C\ N f\ N b$, where $N f$ represents the steady field, $N b$ the field due to the armature, C a constant, and K the force required to set the rotating part in motion. The fields $N f$ and $N b$ are always so arranged that they depend in a simple manner on the current or watt consumption to be metered: consequently one of the fields is made proportional to the current, and the other to the pressure; whilst with an ampere-hour meter either both fields are proportional to the current, or only one variable field is employed; there being a constant field produced by either a permanent or by an electro-magnet.

The following expressions represent the force required, where I is the current to be measured, and i is the pressure current:—

$$K = C_1\ I\ i \quad \text{Watt-hour meter.}$$

$$\left.\begin{array}{l} K = C_2\ I^2 \\ K = C_3\ I \end{array}\right\} \text{Ampere-hour meter.}$$

Velocity must be proportional to the quantity to be measured; the opposing force must consequently be proportional to the velocity. The expressions then become—

$$C_1\ I\ i = A_1\ V,$$
$$C_2\ I^2 = A_2\ V^2,$$
$$C_3\ I = A_3\ V,$$

where A_1, A_2, and A_3 are constants, and V the velocity of the armature.

The first condition can be complied with by employing eddy-currents as the resistance to motion, as these are proportional to the velocity. In the second case air or fluid friction would be employed, which are within a certain range proportional to the square of the velocity.

In the Hartmann & Braun alternating-current meter there is a considerable difference in the strength and phase of the two fields employed.

The constant field is produced by a laminated electro-magnet, almost magnetically closed by an armature wound with many turns of relatively fine wire. The main field is produced by a plain solenoid whose lines of force pass through the iron of the armature in such a direction that a considerable magnetic reluctance is encountered. These meters have an error of only 1 per cent. at 4 per cent. of their maximum load.

This large range is obtained by reducing friction as much as possible. The main field is rendered somewhat unsymmetrical, which produces a couple just sufficient to overcome friction. The same end can be obtained by means of an adjustable iron piece fixed to the magnet.

The consumption of energy in the shunt does not amount to more than 4 or 5 watts.

H. LANGER—SIEMENS & HALSKE CONTROLLING APPARATUS FOR LIFTS.

(*Elektrotechnische Zeitschrift*, 1895, *p.* 663, *No.* 42.)

Motors employed for lifts operate under especially unfavourable conditions,

owing to the necessity of continually starting and stopping, and to the reversal of direction of rotation.

The controlling apparatus usually consists of a starting resistance with sliding contact, operated from the lift by a rope. The switches are specially designed to withstand sparking, carbon contacts being employed for this purpose.

The wire spirals of the resistance are connected to a series of cylindrical rods of carbon fixed in a row to the frame of the apparatus. Above these are fixed a similar number of carbon cylinders to the movable arm of the switch. The carbons come gradually in contact with one another as the switch is lowered. The advantage of this form of resistance is that fewer steps are required than with metallic contacts, and also that the contacts can be easily replaced. In the case of 7-H.P. motor starting resistances, four step resistances have proved sufficient.

In some cases the starting resistance is controlled by a governor worked from the motor axle, and which acts on the switch arm of the resistance. A dash-pot is employed to make the cutting out of the resistance as gradual as possible.

By properly proportioning the number of steps and the resistance the acceleration of the lift may be made as gradual as possible. The advantage of this apparatus is that, should the lift not start owing to overloading, the governor balls will remain down, and all the resistance will then be in circuit. This is more convenient than employing safety fuses.

A special device is employed for closing the field and armature circuits in the correct order, carbon contacts being employed in each case to prevent sparking.

In the case of large lifts it is found necessary to employ starting resistances with 6 to 10 contacts. The spiral resistances are placed in a cast-iron box divided into two parts, and on one side are placed the series of carbon contacts, these being operated by a governor in the above-described manner. The carbons can be adjusted by means of screws fixed to spring arms.

This type of controlling apparatus is used for motors up to 30 H.P.

Special precautions are taken to automatically stop the motor at its highest and lowest positions by a suitable arrangement of switch levers.

This system has been in operation for some years, giving great satisfaction.

CLASSIFIED LIST OF ARTICLES

RELATING TO

ELECTRICITY AND MAGNETISM

Appearing in some of the principal Technical Journals during the Month of JANUARY, 1896.

S. denotes a series of articles. I. denotes fully illustrated.

ELECTRIC LIGHTING AND POWER.

ANON.—The Development of Electrical Works in Cologne.—*E. T. Z.*, No. 1, 1896, p. 12 (I.).

ANON.—Safety Regulations for Electric Installations.—*E. T. Z.*, 1896, No. 2, p. 22 (I.).

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C. H. GUYE—Transmission of Power from Chevres to Geneva.—*Ecl. El.*, vol. 6, 1896, No. 4, p. 147 (I.).

E. J. BRUNSWICK—The Use of Small-Current Arc Lamps.—*Ibid.*, p. 166 (I.).

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EUG. SARTIAUX—The Use of Moulded Glass for Accumulators.—*Ibid.*, No. 4, p. 159 (I.).

ANON.—Iron Fly-Wheels.—*Ibid.*, p. 171.

A. RIGHI—The Method in which Long Sparks are produced on the Surface of Water.—*Jour. de Phys.*, vol. 5, January, 1896, p. 30.

H. D'ARSON—Researches on the Electric Discharge from the Torpedo.—*Bull. Soc. Int.*, vol. 12, No. 123, p. 445.

J. PERRIN—Some Properties of the Röntgen Rays.—*C. R.*, vol. 122, No. 4, p. 186.

M. R. SWYNGEDAUW—The different Action of Ultra-Violet Light on Static and Dynamic Explosive Potentials.—*C. R.*, vol. 122, No. 3, p. 131.

GASTON SÉGUY—On a Crookes Tube of Spherical Form showing the Reflection of Cathode Rays by the Glass and Metal.—*C. R.*, vol. 122, No. 3, p. 134.

M. H. POINCARÉ—Observations on the Subject of M. Jaumann's Communication on the Theory of Cathode Rays.—*C. R.*, vol. 122, No. 2, p. 74–76.

M. H. BAGARD—The Hall Phenomenon in Liquids.—*C. R.*, vol. 122, No. 2, p. 77.

M. J. PERRIN—New Properties of Cathode Rays.—*C. R.*, vol. 121, No. 27, p. 1130.

NOTICE.

1. The Institution's Library is open to members of all Scientific Bodies, and (on application to the Secretary) to the Public generally.

2. The Library is open (except from the 14th August to the 16th September) daily between the hours of 11.0 a.m. and 8.0 p.m., except on Thursdays, and on Saturdays, when it closes at 2.0 p.m.

An Index, compiled by the late Librarian, to the first ten volumes of the Journal (years 1872–81), and an Index, compiled under the direction of the Secretary, to the second ten volumes (years 1882–91), can be had on application to the Secretary, or to Messrs. E. and F. N. Spon, 125, Strand, W.C. Price Two Shillings and Sixpence each.

JOURNAL

OF THE

Institution of Electrical Engineers.

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The Two Hundred and Eighty-fourth Ordinary General Meeting of the Institution was held at the Institution of Civil Engineers, 25, Great George Street, Westminster, on Thursday evening, February 13th, 1896.—Dr. JOHN HOPKINSON, M.A., F.R.S., President, in the Chair.

The minutes of the Ordinary General Meeting held on January 23rd were read and approved.

The names of new candidates for election into the Institution were announced and ordered to be suspended.

The following transfers were announced as having been approved by the Council:—

From the class of Associates to that of Members—

Major G. A. Carr, R.E.
William Brooks Sayers.

From the class of Students to that of Associates—

Arthur Verden Anderson.
Robert Frederick Botting.
Walter Buchanan Browning.
Alfred Cecil Eborall.
Robert Arthur Fullerton.
Douglas Kerr Hall.
Frank Hewer.
Herbert William Jones.
Thomas Richard Davis Kenny.
David Martin.
C. M. Mayson.
Wilfrid P. J. Orton.
H. B. Player.
Basil James Ross.

Donations to the Library were announced as having been received since the last meeting from the Board of Trade; Messrs. C. Griffin & Co.; A. R. Bennett, B. T. Ffinch, Professor G. Carey Foster, Professor A. Jamieson, Sir David Salomons, Members; and Captain W. Goodsall, Associate; to all of whom the thanks of the meeting were unanimously accorded.

Mr. C. N. Russell and Mr. Ernest Talbot were appointed scrutineers of the ballot.

The SECRETARY read the following letter from the Home Secretary:—

WHITEHALL,
4th February, 1896.

SIR,—I have had the honour to lay before the Queen the loyal and dutiful Resolution of Condolence which has been adopted by the Institution of Electrical Engineers, on the occasion of the death of His Royal Highness Prince Henry of Battenberg, K.G., and I have to inform you that Her Majesty was pleased to receive the Resolution very graciously.

I have the honour to be,
Your obedient Servant,
M. W. RIDLEY.

THE SECRETARY,
THE INSTITUTION OF ELECTRICAL ENGINEERS,
Victoria Mansions,
28, Victoria Street, S.W.

The adjourned discussion on the following papers, viz.: "The Electric Wiring Question," by F. Bathurst, Associate, and "Concentric Wiring," by Sam. Mavor, Member, was then resumed.

Mr. Andrews.

Mr. J. D. F. ANDREWS: Mr. President and gentlemen,—I propose devoting my remarks entirely to concentric wiring. Mr. Mavor was good enough, in reading his paper, to attribute the pioneership of this system of wiring to myself, and I have pleasure in thanking him for his courteous remarks and acknowledgment. I might add to what he has already told you that my almost daily practical experience in connection with it has extended over 12 years. The invention, or conception, of concentric wiring, even with a bare outer, is not in itself a matter requiring much ingenuity; but at the time of first introducing it, it was directly opposed to the then existing ideas and principles,

and its introduction was met with by great opposition, more especially by the insurance offices, who at that time almost unanimously followed the Phœnix rules. It is, however, a relief to be able to say that this opposition has now begun to die out, and it is a matter of no difficulty whatever to satisfy insurance offices; in fact, most of the offices regard it in its true light—an additional safety. I may mention here, in compliment, that Mr. Human, of the Guardian Office, was the first surveyor to recognise the advantages of the system from an insurance point of view; and, having once gained the good offices of a gentleman who so thoroughly understood the subject, I was soon able to gain the sanction of the majority of the offices. I was sorry to hear Mr. Mavor make proposals regarding inspection by the insurance offices. I think their policy of trusting in a great measure to the contractors, whose reputation they know to be at stake, a very convenient one; and I do not think it should be suggested that the English contractor will take mean advantage of this trust. This tendency of the insurance offices, moreover, is a proof that they regard electric lighting as quite a minor source of risk, and that it is unnecessary to employ special skill and issue elaborate rules. The Board of Trade has also begun to show a more generous inclination in a direction that will give a wider field to the introduction of concentric wiring. I may, in fact, say that negotiations are progressing satisfactorily with them for my system of concentric mains with a bare, or nearly bare, outer conductor to be laid in the streets of Guildford by the Guildford Electric Supply Company. The system here to be introduced is the three-wire, consisting of two independent armoured conductors, the armouring of both of which combined forms the middle wire. Bare concentric wiring for street mains has advantages for all systems of current-supply—two-wire continuous or alternating, or three-wire. There are, however, special points to be observed in each case. A three-wire system and continuous currents may consist of two armoured cables laid preferably side by side with the two armourings joined together at intervals, say at each house connection, so as to avoid possible electrolysis between them. With alternating currents and a three-wire system the two outer conductors of the system

Mr. Andrews.

Mr. Andrews.

must be enclosed in one armouring, to reduce the induction. In both of these cases the armouring would be smaller in section than with a single two-conductor concentric system. With an earthed concentric system as above described a very much more perfect balance could be maintained than is the case with three separate conductors, because it is a much less complicated undertaking to run the three-wire system into buildings, and, consequently, it could be applied to smaller installations, in each of which there would be two ordinary concentric circuits. The wide introduction of concentric wiring will prove to be of enormous benefit to the electrical industry at large: it considerably reduces the cost of street mains; and the cost of service joints would be less than a quarter the price of the present joint box arrangement. The greatest advantage, however, will appear in the reduction of the cost of interior wiring, which would be considerably less than with casing or conduits systems—quite 20 to 30 per cent., qualities being equal. The wide introduction of concentric wiring is dependent upon a universal permission to earth the distributing network—a permission that would not alone be good for concentric wiring, but would also be beneficial to all systems of street mains, and everything within range of their influence, for the simple reason that the course of leakage currents would be reduced practically to the distance between the two conductors, instead of, as now, the course being of unknown distance through earth, and, consequently, unlimited influence on everything in the course, such as telephones and pipes. To put the principle concisely, if a leakage occurs in a house it will be confined to that house, and would probably cure itself by blowing the fuse. By earthing the network I do not mean that it should be earthed only at one point; on the contrary, it should be almost continuously earthed, or, say, at each house connection. By earthing one of the street mains I do not advocate that it should be bare; on the contrary, it must be protected against electrolysis and possible chemical action of the soil. The earth connection only must be exposed. The benefits to supply companies now using the non-earthed system of such a self-testing system would, I am convinced, entirely outweigh

the cost of making the conversion. With concentric wiring earthed there could, of course, be no leakage currents through earth from wire to wire, and current due to the difference of pressure between one point of the outer conductor and another could be reduced to nothing. The feeders to an earthed network would have to be insulated at the dynamo end, and earthed only at the network end. I understand from various sources that earthed three-wire systems in America and Germany have proved most successful. This concentric system depends for its great benefits, more especially as regards safety, upon two main features. The outer conductor should be absolutely continuous from the dynamo to the lamp; it should be of large section, and entirely envelop the central conductor, also the switches and the fuses. It should be in such close proximity to the inner conductor that it would be impossible for an arc to be established without blowing the fuse. Following these fundamental principles is the only method by which the great advantages of the system can be secured; the reason for which will be obvious when you consider that if the inner conductor is exposed, or easily reached at any point, it would be possible for leakage to take place from it without first touching the other conductors. Although Mr. Mavor has flattered me by following and adopting my devices in almost every part of his system, I am sorry to note that in certain other points his modifications deviate rather considerably from the foundation principles which I have above stated. In introducing a new system like this, it would be a great boon to the trade if the designers would agree upon fixed, definite lines. (There is a board of samples present illustrative of the system as I recommend it, from which it will be seen that every part of the system is enclosed within the outer conductor, with the full thickness of the outer completely surrounding the inner, switches and fuses included.) If concentric wiring were to become general, two important changes may be looked forward to in wiring practice: the test to earth would vanish, and the high degree of insulation now required between the conductors would be looked upon as absurd. The insulating material in a concentric wire should be substantial in character and highly

Mr. Andrews.

durable, but it is only required to insulate to such a degree as not to permit of a greater leakage to take place than may be negligible from a commercial aspect, if it could be possible to obtain reliable insulating material to work at so low a degree; for instance, a wire of 10,000 ohms per mile would only mean a leakage of 1-100th of an ampere with 100 volts—a loss that may be quite negligible. I do not advocate this as the correct degree of insulation to be adopted at present, but simply give it as an illustration; and I would point out that it is 60,000 times lower than is now insisted on in most double wiring. Of course we are accustomed to very low insulation tests on house installations on the double-wire system; this, however, is due to the intricate nature of the system, and great number of exposed points, and not to the length and quality of the wire. With concentric wiring, on the other hand, the tests are generally in proportion to the length of the wire before the fittings are installed.

Mr Wallis-Jones.

Mr. R. WALLIS-JONES: I think it is somewhat interesting to look back upon the progress of electric wiring, say since 1881. If we consider the question broadly, we find that the art of wiring has really divided itself into three distinct periods, which might be termed the "stone age," the "wood age," and the "iron age" If the progress shown continues to follow in the same sequence as the progress of civilisation in other directions, probably the "iron age" has come to stay. The great difficulty in installation work is the question of moisture. If you have absence of moisture, almost any kind of wiring is good enough. I will instance a case in my own experience. Some ten years ago I had to wire a new building. In those days, as you well know, there was no such thing as vulcanised rubber wire in general use. The wires in this installation were simply covered with pure rubber strip, cotton, and tape. I was not at that time certain of the action of various cements and mortars on the insulation of wire, but I did know that the action of plaster of paris on bare wires was at least harmless. I buried the wires in channels cut in the walls, and plastered them in with plaster of paris. At the present moment that installation gives as high a test as any other I know of. That is a simple instance showing that where you have no

moisture you can do with wires of very light insulation. One of the greatest difficulties of wood casing is the very great uncertainty of the action of damp on the cable inside it. I know of one case in particular in which a 19/16 cable was absolutely wasted, so that the conductor was dissolved right away, and nothing remained but the copper salts; and this was traced primarily to a very poor class of insulation around the conductor, and moisture. The wall on which the cable was placed had become damp by the bursting of a water pipe, causing the severance of a cable as large as 19/16. In new buildings, however, before the advent of the insulated conduit system, I have seen very successful work carried out with wood casing, thoroughly well varnished, and put in of a size larger than is absolutely necessary to carry the wire. The casing being buried, plastered over, and left dry, the conductors are then drawn in afterwards. There is no doubt that in a wood-casing installation there are various unmechanical details which are unavoidable. For instance, in going through the walls of houses porcelain pipes are generally used, or, in some cases, rubber tubes; the connection between these and the casing is not easy to make. These are simply make-shifts. Mr. Wallis-Jones.

I would like to call attention to the fact that the bunching of switch wires in wood casing such as allowed by most of the fire insurance offices, and according to the rules as they are at present worded, is open to the danger of getting conductors of opposite polarity in the same groove of the casing, for it is obvious that a switch wire may be taken off either pole.

The question of insurance was touched upon by some of the previous speakers on the last occasion. It seems that the question of insuring a central station is considered by the fire offices upon a very unfair basis at the present time. They make no allowance for difference in the class of building, but charge one rate, whether it is a well or badly designed station. In one very large central station in this country they have taken the matter in their own hands by simply refusing to pay the fire insurance premium, and have fitted up the station with a proper fire-extinguishing plant. Perhaps I may be allowed to say a few

Mr. Wallis-Jones. words upon the interior conduit system, as I have had some experience of an installation of about 800 lamps. As you probably know, there are three distinct classes of this conduit—first, the plain bitumen tube; secondly, the brass-armoured tube; and then the solid iron-armoured conduit. The first, I think, is somewhat fragile, not fire-proof, and certainly is not very sightly when fixed in position on the surface. There is also an intermediate type of conduit, which consists of the insulated tube covered by an iron split tubing. The difficulty in using this appears to me to be in the joining; and, further, it is not at all certain that it will be water-proof—that is to say, I do not think the inner tube can be easily guaranteed water-proof in all sections. As far as present knowledge goes, if you have to wire a new building, especially in the carcass, on the two-wire system, I think there is no system so good as the solid iron tube interior insulated conduit, and for the following reason:—You can take the building in the carcass, and place these iron pipes rigidly in position, plaster the whole of the work up, draw the wires in at the last, when all the plastering work is finished, and be quite certain that you will have no trouble from bad insulation. As an instance of this, I may mention that in the particular installation which came under my notice I tried the other day the experiment of placing a plain steel tape into the conduit for a considerable length. The insulation of that plain steel tape was practically infinity, and therefore it follows that even poorly insulated wire would give very good results indeed. I think the system of an insulated conduit as at present designed can possibly be improved upon in various details. The general way of carrying out work now is to run from the central switch-board a main to a fuse distribution board, and from that fuse distribution board circuits for seven or eight lamps are taken off. Whenever a joint is made a joint box is inserted. But I think the best way of doing work of this kind in the future will be to run a main to the fuse board, and from the fuse board run a sub-main to a fuse joint box, with proper connecting terminals, and then run into the fuse joint box the seven- or ten-light circuits, thus having no joints at all in the system. Twin wires should be used to facilitate drawing.

I have had the pleasure of examining the samples of concentric wiring as shown by Mr. Mavor. I think that where you can have an isolated or separate transformer plant it is a most admirable system, and one destined to be largely used in the near future; but I do not think it is a very sightly one if you are obliged to place it on the surface of buildings. When Mr. Mavor mentioned the sightliness of this system in house work, he was thinking, probably, of the Scotch houses, where they have hollow walls, and you can threddle the wires behind. In English houses, as you know, the system would be placed on the face of the wall, and it would be very difficult indeed to get a straight line with any flexible conductor such as used in the concentric system. I have looked into the question of the case of drawing wires into this insulated conduit system, and find that conductors can most easily be drawn through very considerable lengths. If powdered soapstone is blown in the conduit, it makes it easier to draw in conductors. I should say the average length desirable to arrange for when setting out the circuits of an installation is from 60 to 70 feet run from the distribution point. I find that the total added drawable area of the wires, taken outside the insulation, as compared with the inside area of the conduit, averages something like 45 per cent. I ought to have mentioned that the conduit may be improved by reducing the diameter. This is a very important point with regard to the question of cost, because, unless you have a fairly small conduit, you will have to cut chases so deeply into the brickwork that it becomes exceedingly expensive to instal it. This is apparent when it is remembered that the average depth of plaster is under 1 inch. In that respect, of course, the concentric system has a great advantage. Mr. Wallis-Jones.

Mr. G. L. ADDENBROOKE: I think perhaps it may be advisable, before dealing directly with the question, to say a few words on the financial aspect of wiring. If you take the tables in *Lightning*, you will find as a sort of rough average that a central station, complete with mains, distribution, and everything, costs somewhere about £100 a kilowatt. A kilowatt capacity of plant will light about 15 16-C.P. lamps at once, and, taking 8-candle lamps at 40 watts, about 25 18-C.P. lamps—say Mr. Addenbrooke.

Mr. Addenbrooke. an average of about 20 lamps as taken together, 8's and 16's. On a central station, roughly, about double the number of lamps are installed which are ever required at once. Therefore, if we have got a kilowatt capacity in the station, we shall have about twice that on the lamps; and consequently, on this basis, we shall have about 40 lamps wired for each kilowatt capacity in the station. If we put those lamps down at an average of £1 a piece for wiring, that comes to £40, which shows us that while we are spending £100 in the central station we are spending £40 in the wiring of the houses. It is very easy to run through the tables in *Lightning* and find out how much has been spent in central stations. Of course it amounts to some millions; and if you take a little less than half that for cost of wiring, it still leaves a very large sum indeed as that which has been expended in the past, and will, to an increasing extent, be expended in the future, in wiring. Therefore this wiring question is a very important one, and demands the greatest consideration. For instance, it is greater than any one item in the central station except the distribution; in fact, the cost of wiring is infinitely in advance of the cost of the engines, dynamos, boilers, or any single item in a central station.

I was exceedingly pleased to hear what was said on the subject of earthing the middle wire. I must say that it seems to me that, though it is not quite hopeless, yet it is difficult to make the progress in wiring which we want unless this can be done.

One of the great obstacles to the extension of the electric light—and it is an obstacle which is more felt now we have the Welsbach burner competing—is the great cost of wiring houses, and the frightful mess of the house which it makes. People have to turn out, and have to pay a large decorator's bill besides the cost; and it is a cost, too, that the landlords will not face for their tenants unless the tenants happen to have them in a hole in some way or other. The consequence is that numbers of people simply go without wiring, although the mains are at their doors, and they would gladly bear any little extra cost there would be on gas, because they cannot manage to face the expense of wiring. I think it is almost a duty of everyone who has anything to do with

central station work to do all they possibly can to promote a cheaper and more efficient system of wiring. Mr. Addenbrooke.

There is no doubt that one of the first requisites of a system of wiring is that you should have everything throughout to fit and correspond. I think perhaps that is one of the great reasons why more progress has not been made—that and the constant and intolerable opposition of certain of the fire insurance offices. They have discouraged new work almost as much as they could in many ways. But still it is no good having one thing right—the switch right, the fuse right, or the wire right—you have to have them all right, and the fittings must correspond. Therefore, a good many branches of manufacture must be taken up before the thing can be dealt with. No doubt a great many people have been deterred from going into it on that account; and, consequently, we have gone on with the old, unsatisfactory double-wire casing system. Messrs. Mavor deserve very great credit indeed for the way they have set themselves to work to make a complete system, because there are a great many difficulties to be faced. I have found in connection with my clients that they say, "Oh! but you can only get your fittings "from one house; therefore you will always have to go to them "for fittings, and they will stick on the price," and that sort of thing; consequently any system of that kind has a great deal to encounter, and those who start on it have a great deal of opposition and anxiety before it can be got to go. I think we all hope that Messrs. Mavor, and all those who have worked at concentric wiring, will reap an advantage from what they have done. Certainly, as far as convenience goes, it is the best system, and I can say this—that, having got some estimates for wiring a steamer a few months ago, I had two estimates on the concentric system which were under those of the double-wire system, and my clients are having the concentric system carried out.

There is one point about the earthing of the middle wire in installations I should like to mention. Of course a great deal has been said about electrolysis, and most terrible effects have occurred in America; and any attempt to do as they have done with their tramways would no doubt meet with an absolute veto

Mr. Addenbrooke. on this side. But, when we come to look into it, the problems are entirely different. If the middle wire is only earthed at the distribution points, and not on the feeders, and perhaps only earthed at the houses, you do not get much more than a fall of 3 volts, or 3 per cent., as it is now, from the feeder point to the lamps—3 to 4 volts. Of course half that occurs on one wire, so that the fall of voltage is only $1\frac{1}{2}$ to 2 volts. The amount of that fall which occurs in the house is, of course, only a fraction of that, so that any leakage would only be a fraction of a volt, and it should not be sufficient to set up electrolysis. As regards concentric wiring for houses, I must say I have not absolutely made up my mind whether we shall have to take the wiring simply as it is, or whether the conductor should be put in iron pipes. I hear that some wiring contractors who do a high-class business are putting in a large number of pipes. They find they can put ordinary iron pipes in at something like 4s. a light, and the wires are drawn into these; but they themselves suggested to me that, if the earthing of the middle wire was only permitted, all they would have to do would be to run these pipes, taking a little more care about the joints, and use these iron pipes as the outer, and simply run the wire inside. It seems to me that that would make a very sound job. It would be Messrs. Mavor's concentric system to a certain extent, as far as all the fittings and so on went, and it would get rid of the difficulty of burying the conductors, and they could be drawn out at any time. I certainly hope that this debate will lead to some reform in wiring, because, as I have said, I think the present methods of wiring are blocking progress at present.

Mr. Russell. Mr. C. N. RUSSELL: I have to congratulate Mr. Bathurst and Mr. Mavor upon their papers, which touch upon a subject of so much interest. Taking Mr. Bathurst's paper, which offers many points for discussion, this seems to bring forward as the problem to be solved, "How is it possible to reduce the cost of "wiring to one-half what it is at present?" and, in order to follow the matter, I should be glad if Mr. Bathurst would let us know at what figure he has assumed the present price of wiring. Also, is it proposed that by the use of insulated tubes, we can reduce the

cost of wiring by 50 per cent., or even 25 per cent.? If so, it would be interesting to see some figures of typical installations by way of comparison. The two systems before us, although differing widely, are most excellent, each in their way, and, if installed properly, would do credit to any firm; but at the same time it must be allowed that good work can be, and is, done with wood casing, which is very suitable for face work in rooms that are already decorated and free from damp. I am of opinion that wiring by the use of wood casing can be made to cost less than conduit work. I say *can* be, because wood casing lends itself to bad work by reason of its frailty. It can be cut with a pocket knife, and fixed with tin tacks, and as long as the mitres of the capping are fairly made, the job, when finished, looks all right. On the other hand, however, if a workman is employed who is paid a fair wage, and does his work well, and who is not afraid of taking up the floor boards for his work to be inspected, I do not hesitate to say that the cost of wood casing, *versus* any conduit system, will be about equal, and in a big job will probably be in favour of the latter. Personally, I am much in favour of conduit wiring, and would welcome any system that will reduce the cost of good work; but, while allowing the good qualities of the systems before us, I fail to see any approach to reduction of cost. I have had considerable experience in conduit wiring, with plain iron tubes coated with preservative compound, and can assure the members of this Institution, that the bogies raised by Mr. Bathurst in the way of rust, condensation, &c., have caused us no trouble, although the system is extensively used. So far as my experience has been with conduit wiring, I may say that for mills, workshops, and buildings in course of erection it is well adapted, and makes a first-rate job; but it cannot be done at a price to compete with the so-called cheap wiring, at about 15s. per lamp. The difference in prime cost, between wood casing, and plain iron tubes, having the same duty as regards current-carrying capacity, is in favour of wood casing by about 25 per cent., and in the case of insulated tubes I take it the difference would be greater. As regards prime cost of wiring with plain iron tube conduit, in the case of a mill

Mr. Russell

Mr. Russell. having 120 lights—16-candle power—this works out at 18s. per lamp, where each lamp has a separate switch, and the work was easy and straightforward. These figures do not include main switch-board. I have had a few samples of joint boxes, and fittings as used by the London and Lancashire Electric and General Engineering Company, Limited, placed on the table for inspection by those interested. As far as the merits are concerned of the two systems of wiring before us, I do not think that any practical man doubts their excellent qualities for one moment, but I do not see how either of them are going to assist us in reducing the cost of fitting. To reduce cost it seems as though we must have a new system entirely, possibly a concentric one, with the outer earthed, with lamps and holders that can be fitted with as little trouble as a gas burner. The present form of Ediswan bayonet-joint lamp-holder, so much in use, is, in my opinion, much too complicated, and in too many pieces. Also, the capping of the ordinary incandescent lamp is, I think, capable of great improvement. A number of lamps of the cheap type, which I tested recently, had such a low resistance between terminals across the plaster setting, that in a damp atmosphere, considerable leakage would have occurred.

Referring again to insulated tubes, I do not quite see what is to be gained in the way of economy, by dividing the insulation and placing part on the tube and part on the wire. Taking the comparative areas of the copper conductor, and the inside of the tube, the difference is *enormous*, and it would seem far cheaper to pay for a first-class vulcanised insulation on the conductor than trouble to insulate the whole of the interior area of the iron tube. There is no doubt that a lot of bad wiring is being done by so-called electricians. This is a matter with regard to which I should like to see something done by the Institution. I think it would be well if we could have registered wiremen, something like the registered plumbers, who are, I believe, called upon to pass a practical examination in the work they do. That, I believe, would give confidence to the customers, raise the price of good work, and give us a better chance.

Professor Ayrton. Professor AYRTON: The point to which I wish to draw your attention is rather the wire than the casing; although I may say

I am quite in accord with those who support a conduit system, with which the wires can be drawn in and out, in preference to the old-fashioned wood casing, with which they cannot. What I wish particularly to deal with, however, is the wire itself. Professor Ayrton.

Some time ago I considered this question, Why have electric lighting contractors selected particular gauges of wire to employ? Why, for example, should 1,000 amperes per square inch be selected as the maximum current-density to be used? Why should you allow 2 per cent. rather than 1 or 3 per cent. drop in the P.D., or pressure, between the consumer's terminals and the most distant lamps in the house when all the lamps are turned on? Was there any special reason for those limits selected, or were they arrived at in a purely haphazard fashion?

It appears to me that the contractor and the consulting engineer have rather mixed up two totally distinct considerations, viz., the question of the *safe* gauge, which does not heat by the passage of the current which it normally carries, and the *economical* gauge, or the one that pays best in the long run to employ. If you take the question of the economical gauge, you will find the cross section is far greater than that with which there is any liability for heating to occur in; so that, in fact, as far as danger is concerned, we may almost dismiss the question if we employ such a cross section for the copper as is indicated by the truly *economical* solution.

I am going to suppose, not that I am advising a contractor who wishes to put in the very cheapest work, and so get the contract, and who perhaps may for that reason be led to put in very bad material, but I will imagine that I am advising a householder, or talking to an electrical engineer who himself is advising a householder. In such a case we have to consider what gauge of wire it is the most economical in the long run to use, and not merely what leads to the smallest initial outlay. Curiously enough, the average contractor is not familiar—or, at least, does not appear to be familiar—with the fact that the actual cost of the insulated wire is but a very small fraction of the sum charged and paid for per point for wiring a house. In order to illustrate what I mean, I will give you an example—one of the simplest of the

Professor Ayrton.

many which I have worked out during the last few years, and one which is as good as I can take for those who are in favour of using house wiring of small cross section—I mean an example favourable to those who tolerate a 2 per cent. drop between the consumer's terminals and the most distant lamp when all the lamps are turned on. I will take the case of all the lamps being in the top story. That is not, of course, the usual arrangement, but you will see presently why I select this case. We will suppose that there are 10 16-C.P. lamps in this top story of the house, and that it requires 100 feet of wire to take the current up, and 100 feet to bring it down again, so that 200 feet are used altogether; also, in the first instance, we will assume that there are no other lamps in the building. We will consider what wire you would have to put in in such a case if you were going to allow only a 1 per cent. drop, and what wire if a 2 per cent. drop were permissible; how much the two wires would cost, and what is the difference in price. If you permit a 2 per cent. drop, the actual cost of the insulated wire *alone*, taking 600 megohms per mile Silvertown S quality of vulcanised rubber cable, and assuming that the lamps each take 0·6 ampere at 100 volts, is merely 12s. If, on the other hand, you only allow a 1 per cent. drop, then the cost of this same vulcanised rubber cable comes out at 17s. The difference in cost is, therefore, 5s., for the labour is practically the same. Now is it worth while spending that extra 5s.? Well, in this particular case—and that is why I have taken it—it would be possible to use lamps intended for a lower pressure than was maintained between the consumer's terminals, since all the lamps are supposed to be on one story. Suppose, for instance, the declared pressure were 100 volts, then, if it were possible to have no drop in the 200 feet of wire, we could use 100-volt lamps; if a 1 per cent. drop were allowed, 99-volt lamps; and, if a 2 per cent. drop were permissible, 98-volt lamps could be employed. With the 10 lamps the same amount of light—viz., 160 candles—would be obtained in each case; but with the 1 per cent. drop and the 99-volt lamps about 1 per cent. more current would be employed, while with the 2 per cent. drop and the 98-volt lamps about 2 per cent. more current would be used, than if there were no drop at all.

With no drop at all the yearly bill for electric energy per 1,000 hours, at 6d. per Board of Trade unit, would be 300s.; with the 1 per cent. drop and the 99-volt lamps, 303s.; and with the 2 per cent. drop and the 98-volt lamps, 306s. But, as we have seen, the difference between the cost of the wire for the 1 per cent. and 2 per cent. drop is only 5s.; therefore in two years you would have more than paid away to the supply company the saving obtained by using the thinner wire; and ever afterwards, of course, you would be the loser, if you had put up the thinner wire. Professor Ayrton.

In fact, assuming that these 10 lamps on the top story were always turned on together, and that 6 per cent. interest per year were reckoned on the 5s. extra initial cost spent in wiring, you would not lose by using the thicker wire and 99-volt lamps, even if they were turned on for only 100 hours in the whole year—that is, for only about 2 hours per week.

It is important to notice that the preceding considerations are directly applicable to factories, where a large number of lamps are turned on at dusk, and turned off together when the men leave work. Frequently, I understand, a 5-volt drop is allowed between the factory and the engine-house; but I anticipate that calculation will show that, even allowing for the fact that the price of generating a Board of Trade unit is less than 6d., a much less drop than 5 per cent. gives the maximum economy.

Now, however, take the case of an ordinary house where lamps are used all over the building, and where generally it would be quite impracticable to employ lamps intended for different pressures on different floors, for they would inevitably be interchanged and hopeless confusion would arise. In such a case, if 100 volts be the declared pressure, 100-volt lamps will be purchased and will be used all over the house. Imagine now that we have a separate pair of mains, each 100 feet long, run from the main distributing board in the basement to an upper story, and that, as before, 10 lamps of 16 candle-power are employed in this story, and that they are always turned on and off together. We have not now to deal with 99- or 98-volt lamps, but simply with 100-volt lamps; but

Professor Ayrton. these 100-volt lamps will be run at 99 volts if a 1 per cent. drop be allowed in this pair of mains, or at 98 volts if a 2 per cent. drop be permissible. Now, as you are all doubtless aware, the difference of a volt near the normal working pressure of a glow lamp means about 7 per cent. in the light. So now we have to deal with a difference of not merely 1 per cent. in the power, but of about 7 per cent. in the light; and this, as you will see, leads to a result which is even much more favourable to the consideration which I am urging on you, viz., to spend more on the purchase of the wire, and less on the yearly bill for electric energy supplied.

In the previous example the same amount of light was supposed to be obtained, and the larger drop was made up for by using lower voltage lamps and a larger current; whereas, in this case, 100-volt lamps are supposed to be employed irrespectively of the drop in pressure. Hence, not only will less light be obtained with the larger drop, but a smaller current will be used. This constitutes a partial set-off, which, of course, must not be forgotten in making the comparison. The results are set out in the following table:—

TEN 16-CANDLE-POWER LAMPS AT THE END OF A PAIR OF MAINS, EACH 100 FEET LONG, MADE OF SILVERTOWN CABLE, QUALITY S. DECLARED PRESSURE BETWEEN CONSUMER'S TERMINALS, 100 VOLTS, AT WHICH A LAMP TAKES, SAY, 0·6 AMPERE.

Drop of pressure, in volts ...	Nought	1	2
Price, in shillings, of 200 feet of main	...	17	12
Approximate light, in candles, of the 10 lamps	160	149	138
Approximate current, in amperes, taken by the 10 lamps	6	5·94	5·88
Cost of electric energy, in shillings, per 1,000 hours, at 6d. per unit	300	297	294

By using, then, a 2 per cent. in place of a 1 per cent. drop, we

save, first, the interest on 5s.—the diminished initial outlay—which may be taken as representing, say, 4d. a year; we also save 3s. per year on the bill for electric energy; but we lose some 11,000 candle-hours in the year in the example taken. Now, at 6d. per unit, 11,000 candle-hours, obtained with 60-watt 16-candle-power lamps, represents about £1 0s. 7½d. Hence, by using the more expensive wire, we gain about 17s. a year in this particular case. Professor Ayrton.

If the time of turning on these 10 lamps was only 300 hours instead of 1,000 per year, the gain effected by using the thicker wire would be still about 5s. a year. The 2 per cent. drop is, therefore, an extravagance, and to allow it is an extremely bad investment.

In the preceding I have supposed that the 10 lamps were at 100 feet distance from the consumer's tesminals; but it is clear that, if the distance were much increased, the employment of a higher drop might, on the whole, be the more economical. One of my assistants—Mr. Allen—has made some calculations on this point for me, and he has included in the cost of the wiring, not merely the price of the house mains, composed of S quality Silvertown cable, but also that of the flexible cords supporting pendants; the flexible cord being taken of such a quality that, after 24 hours' immersion in water at 60° Fah., the insulation resistance for each of the wires, after one minute's electrification, is not less than 300 megohms per mile. With such wire he finds that, if the 10 lamps be turned on for 600 hours per year—which corresponds with less than two hours per night—it is more economical to use such a gauge of wire that the drop does not exceed *half a volt* as long as the distance of the group of 10 lamps from the consumer's terminals does not exceed about 350 feet. Hence, with a less well insulated, and, therefore, cheaper, class of flexible cord, such as is much more commonly used in houses, ½ a volt would be more economical than a 1- or a 2-volt drop to allow, even when the group of lamps were more than 350 feet from the main terminals.

The following objections may be raised to the preceding method of reasoning:—

Professor Ayrton.

1st. The lamps on a bedroom floor are often too bright; therefore, if some of the light is wasted by using thin wire, it represents no loss of light causing any practical inconvenience, while using thinner wire certainly represents a diminished initial outlay.

The answer to this is that if there is generally too much light on a bedroom floor, do not fit up bedroom floors with so many lamps, or else use lower candle-power lamps, for lamps may now be bought requiring only some 12 watts at 100 volts. But do not commit the extravagance of losing light by unnecessarily wasting power in the wires.

2nd. It may be urged that the lamps supplied with current from one pair of mains are not all turned on and off at once; that generally the number turned on in a house is much smaller than the number for which the house is wired; and, therefore, that, although a 2 per cent. drop may be permitted at the most distant lamp when all the lamps are turned on, the average drop is much less.

No doubt the way in which lamps are likely to be used in any particular building must be taken into account in deciding on the most economical gauge of wire to employ; but in the case of concert rooms, public halls, restaurants, the auditoriums of theatres, factories, &c., where a considerable number of lamps are turned on and off together, the reasoning which I have used does certainly apply without any modification, and in such cases a 2 per cent. drop is generally a wasteful extravagance.

3rd. It will doubtless be pointed out that no allowance has been made for the money spent on lamp renewals. To this I would reply that we have practically no knowledge of the lengths of lives of 100-volt lamps when *under-run* at 99 or 98 volts; and, further, that if the life of a one-shilling 16-candle-power lamp were 600 hours when run at 100 volts, and even 1,200 hours when run at 98 volts, it would produce no practical effect on my reasoning.

The weakest point in my reasoning, and which I therefore desire to lay stress on, is this: It is known that the light of a new lamp varies with about the seventh power of the pressure, and,

Professor Ayrton.

therefore, that the light falls about 7 per cent. for 1 per cent. drop in the pressure. But does that ratio continue to hold as the lamp grows older? Experiments carried out by Mr. Medley in my laboratory, and extending over two years, would appear to show that in some cases certainly this law does *not* continue to hold as the lamps grow older, if they be *over-run*. But I do not think that this can be taken to prove that it will not continue to hold if they be *under-run;* and as it is only *under-running* that I have been considering in my remarks, I have assumed that, if two groups of similar 100-volt 16-candle-power lamps be run, the one at 99 volts and the other at 98 volts, the light emitted per lamp will continue to be in the ratio of about 14·9 to 13·8 candles.

In order to see how far my conclusion would be modified if the lamps, instead of being clustered in one group, were placed at different points in a hall, Mr. Allen has worked out for me the *detailed* cost of wiring a public hall, 120 feet by 40 feet, for 80 lamps, each giving 16 candles at 100 volts, distributed uniformly throughout the hall—first, for a 1-volt, secondly, for a 2-volt drop. He has taken into account the cost of feeders up to the hall, as well as of lamp-leads, and flexible cords in the hall itself, the feeders and lamp-leads being composed of 600 megohms per mile wire, and the flexible cords of 300 megohms per mile wire; and the feeders (two pairs of which are supposed to be used) are regarded as entering the hall at points 50 feet distant from the entry of the street mains into the building. An allowance has also been made for the difference in the cost of lamp renewals with a 1 and a 2 per cent. drop, so as to make the calculations as complete as possible. The following are his results :—

1. Drop of pressure, in volts, between centre lamp in hall and main terminals of building	1	2
2. Approximate light, in candles, of the 80 lamps	1,190	1,100
3. Price of feeders, lamp-leads, and flexible cords	£ s. d. 21 13 0	£ s. d. 15 3 9
4. Five per cent. of the preceding	1 1 8	0 15 2
5. Approximate cost of electric energy for 1,800 hours, at 6d. per unit	213 15 0	211 5 0
6. Approximate cost, per 1,800 hours, for lamp renewals, at 1s. 3d. per new lamp ...	8 4 2	7 10 0
Total cost per year, items 4, 5, and 6	223 0 10	219 10 2

Hence, in this case, by using a 2-volt instead of a 1-volt drop, we save about £3 10s. 8d. per year, but we lose about 162,000 candle-hours, and this, when produced by 60-watt 16-candle-power lamps, at 6d. per Board of Trade unit, represents about £15 4s.; so that, in this case, by using a 2-volt instead of a 1-volt drop, a loss of about £12 a year is incurred. Indeed, calculation shows that on the whole it is more economical to wire this hall with the thicker and dearer wire, even if the number of hours per year during which the 80 lamps are all turned on be as small as 300—that is, even if the lamps are not turned on for as long as one hour per night.

Another interesting question arises—What is the most economical drop to use? Some four years ago I spent some time attacking this problem mathematically, using various methods of treating it; and the answer I arrived at is a very simple one, viz.—that, if the same person is going to pay the contractor for the installation, as well as, later on, to pay the supply company for the electric energy consumed, the most economical cross section of the copper is generally the thickest that can be used without materially

increasing the cost of casing, labour, &c.; that is to say, as long as the cost of making holes in the walls, the cost of running casing, or conduits, the price of switches, ceiling roses, &c., are not materially increased, use conductors as thick as will give the smallest drop possible. And this result is generally true as long as we are dealing with glow lamps as we now know them, the prices of insulated wires such as are generally charged, and with a Board of Trade unit costing about 6d. Professor Ayrton

This result leads to another very interesting point, viz., it enables a great number of fuses to be dispensed with. The old idea—and you will find it, possibly, still in some specifications—is to put in a fuse wherever the gauge of wire materially changes. Now, is that necessary? If you follow out what I have said about the cross section of the wires, this is absolutely unnecessary. For example, I have here a flexible wire, consisting of 70 No. 40's, which takes a current for a 16-candle lamp at about 450 amperes per square inch. Now, if a pair of such flexible wires—a twin cord, in fact—be joined to two main wires, ought we to insert a fuse at the junction? The answer depends on what current the flexible cord will stand without damage. Well, each of the twin wires composing this cord has had 30 amperes passing through it for half an hour, and you cannot see any perceptible difference in the india-rubber. Doubtless it was not improved electrically, but there is practically no evidence of burning. If, therefore, you have a number of twin cords attached to branch wires, which are themselves attached to a pair of mains, with, say, a 10- or 15-ampere fuse inserted in these mains, the flexible cords are perfectly safe *without* there being any fuses in the ceiling roses or at the junctions of the branch wires with the mains, provided that these branch wires and flexible cords take the working current at about 500—*not* 1,000—amperes to the square inch; and that is the maximum working current-density which I allow for the wires under ordinary circumstances. Of course the insurance company will tell you that is all wrong; but I find their representatives very amenable to reason, and quite alive to the advantage of obvious improvements.

There is another consideration which I should like to mention

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in connection with fuses, dealing with quite another point. It seems to me extremely advisable that an installation should be so divided up that practically about the same fuse can be used everywhere, and when that is not possible, that the fuses ought to be so constructed as to be *absolutely* non-interchangeable. I will not stop to put before you ways of attaining this result, because no doubt you will be able to devise them for yourselves, and so solve that problem of constructing a fuse so that it can neither be put into a place which ought to take a bigger fuse, nor into a place which ought to take a smaller one. There are fuses in the market that meet one of these requirements, but I am not aware of any that can be purchased which satisfactorily fulfil both conditions, and, therefore, an engineer must design such a fuse for himself.

Now, with regard to insulation, I am an advocate of high insulated wire; but I know it will be said that the main leakage is at fuses, switches, and lamp-holders, and that it is no use asking for wire which will have an insulation of 2,000 megohms per mile after 24 hours' immersion in water at 60° Fah., when the greater part of the leakage of an electric light installation is not in the wire at all. But although there is, of course, a certain amount of truth in this argument, it does not appear to me to be wholly satisfactory, since you can clean the switches, you can clean the porcelain, whereas you cannot very well get inside the wire, and no polishing of the outside of the conduit will improve the insulation of the cable inside it.

One of the reasons why so much leakage occurs at switches and fuses is because so many are extremely badly designed. When you look at many a switch or wall plug, you will find, perhaps, two screws which are attached to the main wires at a fair distance apart; and, therefore, there would be a fair surface insulation but for the fact that between them there is another screw which holds the switch or holds the fuse to the baseboard. Hence from metal to metal there is practically no surface insulation whatever. There is no difficulty in designing a fuse-holder or a switch which shall not be materially larger than at present, and yet possess a much higher surface insulation.

And when we remember that higher pressures are certain to be employed sooner or later, it seems very desirable to employ switches which will not only pass muster to-day, but which will answer well when the normal pressure in a house is, say, 220 volts. Professor Ayrton.

However, at no very great expense, it would be possible to replace the switches now commonly put into a house with better insulated ones in the future; whereas, even if a draw-in and draw-out conduit system be employed, it would be a relatively expensive matter to re-wire an entire building, making all the joints afresh, &c., should, in the future, it be found that the present wire is unsatisfactory. Hence, since the extra cost entailed by using 2,000, instead of 600, megohms per mile vulcanised india-rubber wire only represents about 6 per cent. of the price of the insulated wire *alone*, and, therefore, an increase of less than 1 per cent. in the prime cost of the installation, it appears to me that the comparatively small extra sum paid for the better insulated wire is a good precautionary investment.

As to the standard of insulation required for an electric light installation, there has been a great deal of discussion about that subject. You may remember that there was much said on this point at the Board of Trade Conference last autumn. A list is given by Mr. Bathurst in his paper of the standards of insulation employed in different countries for houses, but he has not referred to the high standard which is required now by some of the London supply companies, viz, 80 megohms per lamp. Now, can you get that sort of insulation in a comparatively new building? My experience is that you can, if you use good material and attend to two important points: the one is, always to remove the tape from the end of such an insulated wire, so that this tape never comes into contact with the piece of metal which is part of the live system; and the other precaution to be taken is, be sure that the screws which are used for attaching the wires to the switch, fuse, &c., do not go right through, as they very often do, and make electric contact with the wood or support at the back. If you look after those two points and use good material, my experience is that an insulation

Professor Ayrton.

resistance of over 80 megohms per lamp can be obtained, even in buildings which have only been erected for a few months.

There is just one other point I should like to mention before ending my somewhat lengthy remarks, and that concerns the iron tubes so frequently used now in houses in place of the old wooden casing. It may interest you to learn the result of an experiment carried out some time ago in my laboratory, because I had a doubt if two wires (the going and returning conductors) were drawn into an iron tube, and the wires were somewhat smaller than would fill up the tube, so that they might lie at some distance apart, whether there might not be some perceptible impedance beyond that due to the resistance of the conductors with alternating current at a frequency of, say, 100, and, therefore, whether an extra drop of pressure might not thereby be introduced. Experiment, however, I am happy to say, showed that that was not the case with ordinary iron tubes; their permeability is so low that, even with pretty large currents passing up and back through the comparatively small wires held apart in the tube so as to enclose a certain area, there was not much more drop in pressure than was accounted for by the resistance of the wires.

With reference to a remark made by the last speaker as to an examination for wiremen, it may interest him to know that recently the City and Guilds of London Institute have arranged to hold yearly, not merely a written examination, but also a practical examination to test the power of jointing, and the knowledge of that kind, possessed by the electric lighting wiremen.

Professor Thompson.

Professor S. P. THOMPSON: There is one paragraph in Mr. Bathurst's paper which seems to me very important. It is, that if we have two conductors in a pipe, and one of those conductors breaks down and makes contact with the uninsulated pipe, a new condition of things is set up; and it is that new condition of things that I wish to emphasise. The wire which has made contact with the pipe has now virtually got an increased carrying capacity, owing to the fact that there is a pipe parallel with it, and the other conductor, therefore, will be more liable to overheating. Further than that, the insulation having gone on one side and

Professor Thompson.

practically made an earth—it may be only a local earth for the time being—there is a greater strain thrown on the insulation of the other wire. If we get anything like 200 volts into our houses, it is of the greatest importance that if we have a conduit system at all there should be some kind of mechanical insulation —it need not be a high insulation—inside the pipe itself. There is a great deal to be said for a double insulation. In other conditions of electrical engineering we absolutely must have double insulation—high electrical insulation and high mechanico-electrical insulation. There is this advantage in lining the pipe with an insulating material—it may be with ozokerited paper, or something of that sort—it does prevent mechanical contact between the wire that has broken down for the time being and the iron pipe. A double insulation, I contend, is a distinct advantage. I made an experiment in wiring some years ago. I put myself in the position spoken of by Professor Ayrton. I did not want to save 6d., but I wanted something that was perfectly safe, and would not have an inch of wood casing anywhere. I employed stranded wires highly insulated in most cases, but in one part of the house where there was not the slightest likelihood of damp having any effect I employed a relatively lower insulation. But in every case, whether the insulation was of a really high character or only of a moderate character, the wires were enclosed, each separately, in a lead coating, which was drawn on, and then the two lead-coated wires were put together side by side with a little filling in between, and braided round together so as to form a braided twin. I object altogether to fuses being put up where you cannot get at them—in ceiling roses and other places; I think they ought in such cases to be objected to by the Board of Trade. I would like to have every fuse placed so that it could be replaced without difficulty when the lights were on. I have had no experience of concentric wires. I saw there were o bvious advantages; but, like the wiring in my own house, and like many other examples where wiring has been put in that does not admit of replacement, there is the obvious disadvantage that we cannot materially add to the number of lamps originally

Professor Thompson.

designed for. I have made a few experiments on the likelihood of different kinds of conduits breaking down, but they are not in such a state that I can quote them yet; but it seems to me to be a great point that there is greater safety where a pipe, if of metal, is lined with a fairly strong and fairly good interior insulating material.

The discussion was adjourned until the 27th February.

The PRESIDENT announced that as the result of the ballot the following candidates were elected:—

Associates:

Charles Henry Biggs.
Alfred W. Fell.
Frederick Richard Flew.
Albert E. Mohring.
William Edward Moulsdale.
Gilbert C. Vyle.

Students:

F. R. Bridger.
William Bunn.
Eric Mortimer.
Claud Edward Vance.

The meeting then adjourned.

The Two Hundred and Eighty-fifth Ordinary General Meeting of the Institution was held at the Institution of Civil Engineers, 25, Great George Street, Westminster, on Thursday evening, February 27th, 1896—Dr. John Hopkinson, President, in the Chair.

The minutes of the Ordinary General Meeting held on February 13th were read and approved.

The names of new candidates for election into the Institution were announced and ordered to be suspended.

The following transfers were announced as having been approved by the Council:—

From the class of Associates to that of Members—

Adam S. Barnard.

From the class of Students to that of Associates—

W. R. T. Cottrell. | Edward Ernest Hoadley.
Frank B. Wily.

A donation to the Institution was announced as having been received since the last meeting from Mr. G. G. Ward of a framed photograph of a picture, lately presented to the New York Chamber of Commerce, of the projectors of the Atlantic Cable.

On the motion of the President, a vote thanks was duly accorded to Mr. Ward for his handsome presentation.

Mr. J. S. Fairfax and Mr. A. C. Ford were appointed scrutineers of the ballot.

The adjourned discussion on the papers by Mr. F. Bathurst and Mr. Sam. Mavor was then resumed.

Mr. Binswanger. Mr. G. Binswanger: I should like to add a few words to the discussion as to how I view this matter of wiring as a manufacturer. The question whether this or that system of wiring should be adopted for any particular installation is a question to be decided by the contractor. We manufacturers have to find out what demand is likely to arise. Personally, I come in contact with a good many contractors, and I have found a general consensus of opinion that wiring in wood casing must some day or other be superseded. It certainly is not a system which recommends itself to the fancy of an engineer or an architect. I have also found amongst contractors an idea that fire insurance companies, especially the Phœnix Office, recommend, or even insist upon, the use of wood casing. I may say that such an idea is erroneous. Mr. Heaphy certainly has passed wood casing, because, as he has often told me, from his point of view he never had a failure—he has never had a fire to record. But if any system could be proposed which gave him the same security—and, after all, the consideration of fire risk is the very first we have to study—and if such a system should present advantages to the engineer and to the architect, I am sure Mr. Heaphy will be one of the foremost to recommend its adoption. Contractors have often asked me whether, if they adopt any of the new systems proposed, they would be readily able to obtain the materials required, and at reasonable cost. My answer is, that of course the question of supply depends upon the demand. The larger the demand, the more ready the supply. As to cost, this must, and does, depend, to my mind, largely upon the contractor himself. If he enables the manufacturer to lay down a plant to manufacture cheaply, no doubt the cost of the material will be low. The material required for wood casing has had an enormous sale during the last 10 years, and, naturally, the cost of such materials is at the present moment very low. To compare, therefore, the cost of installations on the new methods proposed with that of the old methods is, to my mind, unfair to the new methods. Some previous speakers, however, have tried to do so. I can predict—confidently, I believe—that, if either of the two new systems proposed has only one-tenth ·t of the run of the old wood casing, the cost of installation

of conduit or concentric method, both as regards labour and material, would compare, and compare favourably. Another question, which refers to the matter of cost, and which also, to my mind, is in the hands of the contractor and consulting engineer, is the question of standardising. Let us at the very beginning, if a new system is proposed, adopt standards, and let every contractor use nothing else. Let us use as few parts in an installation as we can. The questions of the size of the wire, especially the insulation of the wire, and whether one or two wires should be put into a tube, the size of the tubing, the pitch of the screws, and the many different accessories—all these should be standardised by a competent authority, and no contractor should use anything else. What struck me most in Mr. Mavor's very excellent paper (I do not refer to his rather unkind remarks about crockery ware) was his successful attempt at standardising. The same may be said of Mr. Bathurst's system, which also lends itself very much to be standardised from beginning to end. But, let me ask, what about the future? If concentric wiring, or the conduit system, should be largely adopted, we shall have, not one or two, but one or two dozen manufacturers making the materials required; and, if we continue our bad habits, no doubt every one of these manufacturers will have his own patents, his own methods, gauges, sizes, &c., which will differ from those adopted by his neighbour just sufficiently to prevent interchangeability, and standards there will be none. It is rather superfluous, I believe, to speak in this room about standardising. We all know the great evil under which we suffer in England from the want of standards in manufacture. Why should we manufacturers have to wind, or make, for instance, different alternating-current motors, alternating meters, and alternating arc lamps, simply because so many different periodicities exist here in England in alternating stations? I think, however, the remedy is very easy. I would suggest that some committee should be appointed by the Institution to give us standards. I believe every manufacturer in England would be glad to adopt the same; I am sure 90 per cent. of the contractors would welcome such action;

Mr. Binswanger

Mr. Kinwarger. how many consulting engineers would adopt such standards I am, without consulting them, hardly prepared to say.

I think that the present time, when important new matters are developing in the electrical industry, such as motors for transmission of power, electric traction, new and higher voltages on our central stations, and to-night, when discussing new systems of wiring—now is an opportune moment to agitate for the appointment of such a standardising committee.

Mr. Hall. Mr. H. CUTHBERT HALL, in reply to an invitation from the President, said: I find, after carefully reading the reprints of the discussion which has already taken place on these papers, that the few points I intended to discuss have already been very effectively dealt with by other speakers, and, therefore, I will not take up the time of the meeting.

Mr. Boot. Mr. H. L. P. BOOT: Taking the discussion so far as it has gone, very few members seem to realise the great importance of the question at issue. Whether we are central station engineers, manufacturers, or whatever we are, everything depends upon this one wiring question. I think it would be well if attention were paid to one or two points, especially the low cost per point wired. If a person has his house fitted with the electric light—which is very usual nowadays—he will get an estimate for fitting with gas at the same time; and if you compare the two costs it is simply ridiculous, electric wiring costing so much more than gas pipes. I know that a cable is far more expensive than iron pipes; but at the same time, unless we adopt some system by which we can reduce everything to its lowest cost, I do not see that we are going to do any better by introducing any fresh systems, but would introduce fresh complications. The most important items are, the low cost per point wired, durability, damp-proof, elegance should be considered, fire risk reduced to a minimum, and small destruction of premises necessary. An installation should be able to be put up by any ironmonger of repute. Undoubtedly this wiring business, especially in provincial towns, is bound to fall into the hands, so to speak, of "jerry" wiremen. It is impossible to keep it out of their hands; in fact, it is not altogether to our advantage to place too many restrictions, if we

want to see everybody going in for electric lighting the same as Mr. Boot. people put in gas. Simplicity has a great deal to do with the merits of any new system. It is scarcely necessary for an ordinary wireman to go into the most economical area of wires, as proposed by a speaker at the last meeting. I think it would be much more sensible if, when putting wires in, we did not reduce them so much as is done in present practice; it would then reduce the number of cut-outs, which means labour. An average comparison of the cost per point wired shows that, where good work is done, it is the carpenters, joiners, and wiremen who cost money, and not the actual materials supplied. If we could reduce this labour, and make the systems of wiring so simple that any ordinary man of intelligence could use them and put them up rapidly, we should certainly help the electrical engineering industry as a whole. A great many members are under the impression that the electric wiring contractor should be a "specialist" only; this, I think, is a mistake, if the industry is to develop by leaps and bounds. In provincial towns (of which I can speak with a little authority) it is a very usual thing for clients to have gas and water put in by their local ironmonger, and they go to him for electric lighting. If he does not undertake it—which is quite possible—the consumer says, "I will not be troubled with it, then." Therefore the chief point to remember is simplicity of design; and unless a system can be invented—which, I am afraid, is not the case with either of the two systems before us—more simple than casing, it is almost unadvisable to suggest new systems. Probably the reason the tubular system comes out dearer is undoubtedly because it is not adopted generally. If it had been on the market as long as casing, it is quite probable that it would come out very much cheaper. With regard to Mr. Mavor's concentric system, I think my experience tends to show that the fittings come rather expensive, and that it requires a special class of labour; and I was rather surprised that he should claim cheapness for it. So far as ship-lighting is concerned, it is the best and cheapest system; because wood casing is out of the question. But for ordinary buildings, as erected at the present time, I do not

Mr. Boot. consider it comes out cheaper. If the members who read the papers had kindly given us a few more particulars as to how the cost was made up—how much for labour, and how much for alterations and various items connected with wiring—we should probably be able to judge, and compare the systems with the present casing one. We should then see what is saved by doing away with casing, and how much is allowed for labour, and *vice versâ*. Whatever the effect of the discussion may be, I trust the Institution of Electrical Engineers will endeavour to standardise the systems, so far as holders, &c., are concerned.

Mr. Rawlings. Mr. W. R. RAWLINGS: In the coffee-room last week Mr. Bathurst said, "I wish they would tell us whether we are right "or wrong." Now I am not in the position to tell him one thing or the other, but I should just like to point out what I consider to be a defect in the tubular system as exhibited here by our friend Mr. Bathurst. The tubes themselves are not flexible; the most flexible ones he has are those which are not covered with metal. It is no use saying you can do without a flexible tube, because, as all contractors know, they are asked to place wires behind valuable cornices, and are not allowed to cut them; and unless the tube is a flexible one it does not answer all the purposes for which it is required. There is another very important point, too. I consider that, besides being flexible, it should be, where buried beneath the plaster, nail-proof, for, in spite of Mr. Mavor's bogey, I have been myself the cause of withdrawing more nails in connection with conductors than I have upon my hands and feet combined. I am sure if Mr. Mavor had only had a little experience with the modern decorator, who makes up panels on the wall with about three parts of wood moulding and the other part made up of 2-inch wire nails—I think he would alter his opinion when he says you can place your wires indiscriminately on the wall beneath the surface of the plaster. This brings us to the insulation test, which, as Mr. Bathurst points out, is somewhat of a myth. The insulation test does not find a nail unless it is in a damp place. I have myself withdrawn a nail which had been in circuit for over two years, which had passed all the tests in use, and which was only found out then by

accident. While on the insulation test I should like to point out that I consider the unit is somewhat of a myth also. We are in the habit of taking per lamp. By way of an illustration, look at a small shop, which is fitted very often with 10 pendants, six lights on each, hanging from a flexible cord, each pendant having its own switch. There we have practically only 20 points to bring down the insulation. In spite of what Professor Ayrton said, I contend that in practice it is nothing but the points of the wires exposed and fitted on the switches that does bring down the insulation. Then compare those 20 points for the 60 lights with a well-fitted house with 60 lights, having 55 outlets for those lights, and probably 50 switches, making 105 points to bring down the insulation. This, I contend, is very unfair to the contractor, for, while he is asked to give a certain insulation per lamp in one case, he is not asked to give more in the other. Mr. Mavor rightly points out the question of the labour trouble. It is, I think, the duty of this Institution to stamp out the workmen who are going about—the scum of other trades—who call themselves wiremen. I understand that the City Guilds of London are doing something in this direction; but whatever they may do to qualify the men, they cannot make the men honest, for it is honesty of purpose which we require in our men. Only a few weeks ago we had exhibited on the table specimens of bad joints which were supposed to have been put in by a firm of repute. There is not the least doubt that the firm of repute had every reason to believe their installation was well put up, and had the men who were employed in the work had honesty of purpose the bad work would never have happened. I would suggest that this Institution should have a method of registering the men —not the City Guilds of London, but this Institution—and if the members would support those men, and, if necessary, blackball those who do not come up to the standard of honesty which is so very necessary in carrying out this work, I feel sure there would be no more bad joints, &c. Mr. Mavor, with his concentric system, may fit up a factory, and do it, I believe, better than with wood casing or tubing; but with a private house I should like to ask him how he would fit up a bracket of the Louis order, which Mr. Rawlings.

Mr. Rawlings. cannot be turned round and round when it is required between the mouldings, and more especially if he has two or more switchings to that bracket. I should like to ask him also how he would add one or more switches to a light at a reasonable cost; for I notice that to each switch there are practically four wires to one of single action.

Mr. Human. Mr. H. HUMAN: When reading over the two papers under discussion, I fully recognised that the fire office question was bound to crop up, and would become a red herring in our path; and I knew, therefore, that I was in for a bad quarter of an hour. Well, those who were present on the first evening of this discussion will understand, perhaps, what my feelings, as a fire office surveyor, must have been on that occasion. To say the least, it was somewhat warm; and though I should much prefer ignoring that part of the subject, I cannot overlook the fact that that red herring has been very prominent during this discussion, and was, moreover, so very vigorously handled by Major-General Webber, who brought it so very painfully under our notice, that to ignore it is absolutely impossible.

Let me, then, say at the outset—and I speak only for myself—that I agree with a good deal that has been said here anent fire office inspections of electric installations. I admit that many of them are more or less a farce, and must necessarily be so. Indeed, I will venture to say that fully nine out of every ten of such inspections might well be dispensed with. I am convinced that the number of inspections now made by fire offices, in connection with electric lighting, is nothing less than a sinful waste of valuable time, and, what is more, wholly unjustified. Depend upon it, the day must come when the electrical inspector, pure and simple, of the fire office will have disappeared from the scene, and his rules relegated to the lumber room—or perhaps to some museum as a curiosity of the past. Having made that confession, let me briefly notice some of the comments upon fire office forms. Again I agree that some of those forms are unnecessarily long—they attempt too much. Now a form is a very useful thing in its way, when kept within moderate limits. It serves as a record, in the first place, in the books of the company, and, in the next,

enables one to judge as to whether there is anything of a special nature calling for further attention. But a few simple questions, easily put and as easily answered, should suffice. Above all, let us avoid possibilities. That reminds me of a form filled up by a well-known member of this Institution, who, in answer to the question as to whether it is possible for water or moisture to enter somewhere or the other, replied, "With the Lord all things are "possible." Yes, some of those forms are very entertaining reading, and I notice in particular that contractors have a remarkable affinity for the word "infinity" when speaking of insulation. Well, I hope they know what they are about when they use it. Let me say that we possess ample documentary evidence to prove, if needed, that, should this Institution recommend that all tests for insulation should show infinity, there would be no difficulty whatever on the part of the contractors in meeting that little requirement. I now come to the main attack—to that vigorous onslaught by General Webber upon the fire offices. That gentleman appears to be very much incensed at the rating now applied to central stations. Well, I can quite understand his feelings in the matter, but I would, nevertheless, beg of him not to put the whole of the burden upon the one animal. When those stations first came up for consideration, they were regarded favourably by the fire offices. It was thought there was nothing very alarming about them, and that they would prove remunerative risks. It is true we were not quite so innocent as our friend of the other evening who hailed from Oxford, who appears to be under the impression that iron and steel cannot be injured by fire—no, they knew better than that; at the same time they (the fire offices) thought so well of them that they practically scrambled for them—that is to say, they accepted them at exceedingly low rates. Well, as usual, they have now bought their experience, and, let me add, paid for it pretty dearly. Yes, I am sorry to say there is a big deficit against you at the present time. Now there is no sentiment whatever in the matter; it is purely a business transaction. We may not be, as you are, concerned in the conservation of energy, but we are very much concerned in the

Mr. Human.

Mr. Human. conservation of pounds, shillings, and pence. We find that not only have we underrated those risks, but have, in consequence, undersold our indemnity, and as business men are simply rectifying that little error by raising our rates. But General Webber apparently objects to being tarred with the same brush as his friends. Well, I must say I sympathise with him, for I know what that operation means. Let me say we fire office surveyors too often come under the one brush at the hands of you gentlemen in electrical matters. But in General Webber's case I fail to see how that can be obviated. It must be remembered that when you come under a special classification—that is to say, when you form one of a class which has been specially legislated for—there must be no exemption in favour of individuals. That may act harshly, I know, in individual cases, in the same way that Acts of Parliament very often do; but then you cannot legislate for individuals. No, it is our common experience, unfortunately, in this life that the good have to pay for the bad. That may be poor consolation for General Webber, but it is the best I can offer him under the circumstances. But that gentleman does not stop there. He complains very bitterly that the fire offices do not sufficiently recognise the benefit of electric lighting by making reductions in its favour. In other words, if the fire offices would only make such a reduction in favour of electric lighting as would practically recoup the insured for the outlay of installing it, what a glorious thing that would be for the electrical industry! Quite so; and all the sweeter from the fact that it would be at the sole and entire cost of the fire offices. But when General Webber went on to refer in particular to those extensive warehouses in our several seaports, I was simply aghast. Do not imagine that the one and only risk in such places is the lighting. Let me say that of the big dock warehouse fires in the Port of London during the past few years, most of them occurred in buildings in which there was no form of artificial lighting whatever. Conceive, for instance, a case where in such warehouses we may have goods liable to spontaneous ignition. Are we to infer that the mere introduction of electricity will reduce that risk one single iota? No; to allow for electric

lighting in such places would be indeed straining at a gnat and swallowing a camel. The risk, let me say, in those warehouses is inherent in the varied nature of their contents, and lighting or no lighting, electricity or no electricity, they must of necessity bear a high rate. Mr. Human.

Whatever may be the case in the future, I will venture to say that up to now the fire offices owe nothing to electricity. Look at London alone during last year. In 1895 there were 570 more fires than in 1894. And the total for 1895 exceeded the average of the past 10 years by no fewer than 1,016 fires. A nice little bill for the fire offices! Not in consequence of—no, but, nevertheless, in spite of—electric lighting. And when we look into causes we find there are a very large number—a very large proportion—for which no cause can be assigned. They constitute the unknown; but among those unknown, let me say, there are causes which all the electric lighting in the world will never redeem.

Mr. J. N. Shoolbred: There are many points in these two papers which are of considerable interest, but I will only make a very few remarks on one particular point—that is, with regard to the table of insulation tests which Mr. Bathurst puts in his paper as Appendix B. In the first place, I am very glad to see that he adopts in that table as the basis of the test the "ampere," and *not* the "lamp," as is the case with several of the many rules we have in use in this country. The word "lamp" tends to confusion, some people imagining it is an 8-candle-power one, others that it is a 16-candle one; and, when the question of arc lamps crops up, the confusion gets worse. But it is when motors, electro-deposition, and various other applications, are introduced, that it becomes evident that the "ampere" *must* form the basis of the test, and not the lamp. At present there is a question of raising the voltage in the lamp; and that, again, will affect the amperage, and make still greater confusion. Therefore it appears decidedly that the lamp is *not* the basis to be adopted, but the quantity of current used. Of course there is no reason why the voltage as well should not be taken also somewhat into consideration, but the essential Mr. Shoolbred.

Mr Shoolbred. basis is the current used. In confirmation of what I am saying, I may mention that in 1889, after discussing with Major Cardew some regulations in connection with the wiring of consumers' premises which were proposed by the Corporation of Bradford, the Corporation were glad to adopt a very important suggestion of Major Cardew's on this matter of the insulation test, which was incorporated by the Corporation in their regulations. It has worked satisfactorily during the past six years, and there has been no trouble and no complaint on the subject; indeed, several contractors engaged in wiring have stated that some such basis should be universally adopted. That clause provides that "The insulation resistance of the entire installation, "measured at the house terminal box, between the extremity of "either of the house mains and the earth (when all the mains, "wires, fittings, lamps, motors, and other appliances are fixed), shall "not be less than the total number of ohms which shall be indicated "by the number resulting from the division of 10,000,000 by the "number expressing the maximum electric current, in amperes, "which has been named by the consumer in his application for a "supply of electricity." Or, to put it briefly, 10 megohms divided by the maximum number of amperes asked for. Respecting the concluding words of the clause, about "the maximum "amount of current named by the consumer in his application for "a supply of electricity," Major Cardew lays some stress upon them, inasmuch as the Board of Trade Orders distinctly state, that all consumers are to make their application in terms of the electric current required; the insulation test and the application of the consumer thus becoming (in the above regulation) closely connected to each other. It is a very simple thing to mark, say in red ink, as a record on the application form itself, the exact amount of the insulation test which the installation must comply with in order to be satisfactory.

The following are the results of the application of this test. They are given in precisely the same terms as are the various results given in the table in Appendix B, for the purposes of comparison therewith.

Mr. Shoolbred.

ENGLAND (BRADFORD CORPORATION). $\dfrac{\text{10,000,000 OHMS}}{\text{NO. OF AMPERES}}$.

Amperes.	Ohms.	Amperes.	Ohms.
10	1,000,000	400	25,000
25	400,000	500	20,000
50	200,000	800	12,500
100	100,000	1,000	10,000
200	50,000	1,600	6,250
250	40,000		

In the table in the Appendix B, under the heading "England "(London)," it is difficult, at first, to recognise the requirements of the Phœnix Fire Office. The 10, 25, 50, 250, and 500 "amperes" of the table should really read as 25, 50, 100, 500, and 1,000 "lights;" the basis of this rule being expressed by $\dfrac{\text{12,500,000 ohms}}{\text{No. of lights}}$.

There is another rule much used in England by the Brush Company, whereof the base is $\dfrac{\text{75,000,000 ohms}}{\text{No. of lamps (irrespective of size)}}$.

Lamps.	Ohms.	Lamps.	Ohms.
25	3,000,000	200	500,000
50	1,500,000	250	300,000
100	1,000,000	300	200,000
150	750,000		

In the recent discussion relative to the revised Board of Trade Regulations, the Council of the Institution of Electrical Engineers advocated a similar basis of test under the head of "75 megohms divided by the number of points where the current "is taken off."

In these two last-named bases of test, the anomaly already

Mr. Shoolbred. pointed out, due to the use of the word "lamp," is attached; while the "Bradford" basis above referred to, besides being applicable to motors, as well as to arc lamps and to incandescent lamps of all degrees of current (while adapting itself to the current-density in each case), demands more than the Phœnix test, though without being so severe as the Brush one, which really appears excessive in its requirements.

Mr. Dykes. Mr. A. H. Dykes: It appears to me that the question, Which is the best system of electric wiring? is on a par with the question, Which is the best engine? or, Which is the best boiler? it simply depends on the circumstances of the case. In fact, practically every system which has been mentioned is good in the proper place. For instance, we have heard a good deal in dispraise of wood casing; but I maintain, if proper care is taken and the wood casing is put in proper place, you can make quite as good an installation with wood casing as you can with any other method. But, on the other hand, you must not go and put wood casing in a building which is obviously not suited for it. I have in my mind an installation where, I think, we have a sample of pretty nearly every kind of wiring which has been mentioned. There are certain rooms in it which are panelled: there one would naturally put in wood casing to match the woodwork; and if that is properly put in, and the circuits properly fused, I contend it is as safe as the rest of the work. There are other parts of that same installation where the wires are simply run in iron pipes, coated with preservative composition—places such as conservatories, stables, and so on, where it is important to have the wires thoroughly protected, and where there are no decorations to be studied. There are other parts of the same installation where the wires are run in compo piping, these being places where it is absolutely impossible for the wires to be touched by nails. There are rooms like that in all houses. To take one case, which will occur to everybody, walls covered with tapestry, where the only way of getting at it is to simply push a fishing rod at the back with a wire on the end, pull it through a hole made in the tapestry, pull the wires up, and then thread compo piping over them. It is the only way to

wire a place of that sort, and as you are not likely to put a nail through tapestry it is perfectly safe. The concentric system of Mr. Mavor's certainly possesses very considerable advantages where you are able to use it. It has the great advantage that all the trouble which is generally experienced in trying to keep up the insulation from earth is done away with. All that one has to consider is the insulation between the positive and negative main. That is an important point, but it is a point which does not call for the notice of either the fire insurance inspector or the supply company. You might have a low insulation resistance on a system of that kind, but unless it is low enough to blow the fuses it can do no serious damage. It does not matter what system of wiring you use; it seems to me the trouble is not in the wire or in the conduit system itself; it is practically always in the accessories—the switches, fuses, and so on. If you only make the switches, cut-outs, wall sockets, and so on, properly, you can pretty well use any system of wiring you like; provided, as I say, that you suit your system to the place where you are installing it. We are told by Mr. Bathurst that if you use iron pipes to carry the wires you must insulate them inside. Well, I maintain that is entirely wrong. If you are going to use an iron pipe, then do not insulate it at all. If you have leakage from your wires, then let it go direct to earth, blow your fuse, and it is all over. That means, of course, that you must break up your system, and only use comparatively small fuses; in fact, I go so far as to say that you should not use anything larger than 3/20 circuits carrying five or six lights. Mr. Dykes.

For the class of buildings which is now being generally erected for insurance offices, banks, and public halls, in which the flooring is of wood blocks laid direct on the iron and concrete fire-proof floors, and the walls faced with marble, tilework, or hard plaster, I am of opinion that the iron pipe system offers advantages over all others; and, as my firm has had some considerable experience with this system, a few particulars may perhaps be of interest.

To begin with, we find that such work costs no more than good wooden casing in a similar building. The pipes are laid as

Mr. Dykes. the work goes on, the cement floors being floated over them, thus avoiding the usual cutting away of plaster, floors, &c.; and, although the pipes may be in position months before they are covered by the floor blocks, tiles, or plaster, not a single yard of wire can be damaged by workmen. The usual heavy joiner's bill, too, is, of course, done away with.

There is no trouble in getting a very high insulation—as high as with any other system; it only means, as usual, that fittings, switch-boards, and other accessories must be well insulated: until these go up the insulation is practically infinite. As the current is generally switched on in sections as the work is finished, it is difficult to get a test of the installation as a whole; but I may mention that at a City bank, wired on this system to our specification, a test taken a few weeks back on completion, and repeated once or twice at weekly intervals, gave $1\frac{1}{2}\ \Omega$ above earth for 135 lights. A test taken yesterday at a similar building on a section of 40 lights gave a very slight movement on the ohmmeter, which is calibrated up to $5\ \Omega$. In both these cases the switches are let in flush with the tilework, and in the former case there is a large number of points on glazed brickwork in the underground cellars. At another installation in a private house where a mixed system is used, a test last week gave $2{\cdot}9\ \Omega$ for 114 points, there being four distributing fuse-boards.

These figures show that it is not at all impossible to get a very high insulation by taking a few precautions; although at the same time I must say that personally I put little trust in insulation tests as a guide to the condition of the installation.

We have an iron pipe installation of about 430 lights where all switches, as usual, are sunk in the tilework, and hidden by fancy metal cover plates. In this instance switches of "tumbler" pattern were used, the flat cover plate being screwed on in place of the usual metal covers. With these plates off the insulation tested out quite as well as the rest; but when the covers touched the tilework, the leakage over the numerous switches was sufficient to bring down the insulation very considerably, although still above the ordinary fire office requirements. This can be partially remedied by slipping a piece of mica between the plate and the tilework.

Fuse boards—which should be of marble, as slate is so unreliable—require to be carefully insulated on porcelain or ebonite insulators from the iron frame, or wood bearers; if the marble touches the iron at any point, down goes the insulation. Mr. Dykes.

The ideal system would be, of course, to connect all fittings, electroliers, and standards direct to the iron pipes, simply insulating the holders; but at the present time it is impossible to get sufficient insulation between the frame and the lamp-holders to allow of this, and it is necessary to carefully insulate the fittings themselves from the iron pipes.

One point, in conclusion, seems to be of importance—the question of gas mains touching the iron pipes. I would urge that all the iron piping should be continuously connected throughout, and that efficient earth connections be made at one or two points, when it will not matter whether the pipes touch gas or water pipes, or, as is certain to happen, the iron joists of the building.

Unless these precautions are taken it is conceivable that serious consequences may follow.

Mr. R. E. CROMPTON: I shall only say a very few words, and those few words lose a great deal of their point because they are at the wrong end of the discussion. I had intended in the month of December last, when the papers were read, to open the discussion by pointing out to the members that a committee had been sitting for some months to revise our wiring rules, and that the members of that committee looked forward with great interest to the discussion that would certainly follow these two papers, as the question of casing and the various systems of conduits and concentric wiring had been under their consideration, and we hoped to hear the experience of members with regard to the use of these various methods. To a certain extent we have been disappointed in this, and I regret very much that so few remarks have been made by those who have used these systems, and who, we had hoped, would have given us their experience. It appears to me that we are on the eve of a very important revolution in the art of house-wiring. The new Board of Trade Regulations, in allowing us a greater pressure, are also stipulating that the side of the system should be earthed; therefore we have Mr. Crompton.

Mr. Crompton. to contemplate a new condition of affairs. We have really now to consider whether this will not allow us to at once direct our ideas to the cheapest and simplest system of wiring, which I think has been already mentioned by one speaker in the first evening's discussion, namely, that of putting one highly insulated wire concentrically within a pipe which at the same time forms the casing and also forms the return wire. This appears to be an exceedingly simple and cheap arrangement; and although it may appear, perhaps, to those accustomed to the present system to have disadvantages, yet I think that when the whole system is thoroughly thought out we shall really get to that in the end. We have to thank Mr. Mavor and Mr. Andrews for having practically been the first to lead us in this direction. I think I am one of the first speakers really to do some justice to those gentlemen. My firm has used, I believe, a very considerable amount of concentric wiring, and it has been so successful that I was surprised to hear so little said in praise of the system by other speakers. It has been more used in factories and places of that kind than in private houses; but it has been used in very difficult situations, in places where it would have been difficult to obtain high insulation by ordinary methods, and it has obtained this insulation by what I may call the air-tightness of the system. Every part is enclosed, and the insulation resistance is kept up by preventing the entrance of damp to all those weak points to which a previous speaker has called attention, *i.e.*, the points at which the fittings are attached to the wires. It appears to me that the concentric-wiring gentlemen are the only ones who have drawn attention to the importance of protecting those points by making a continuous casing up to those points, so that the air, and hence the damp, can be excluded from the insulation. The fact that it appears to be so easy to do this with the concentric system, and so difficult to do it with the double-wiring system, is very much in favour of the concentric system. There is another point which has not been made as much of as it should be, namely, the lamp fittings. Mr. Mavor noticed it, but did not make very much of it. Concentric fitted lamps are certainly superior to the ordinary double-wiring ones. I think we shall

find that the double lamp fittings we have been using for some time past are a very expensive affair to maintain in order, which all householders who use electric light are finding out daily. The reason is very obvious: the makers have to get a number of small parts into a confined space, and it is extremely difficult to make a small comely fitting, containing such a number of small parts in such close proximity, and to get sufficient insulation between them. The concentric lamp fitting is comparatively free from these disadvantages, and I think you will probably find other points where the concentric fittings allow of greater insulation simplicity. I wish very strongly to say that the real good thing we have got out of this discussion (I am speaking from the point of view of the committee for revising the rules) is that there has been rather a strong condemnation of casing, and I think the days of casing are evidently doomed. I think there is no doubt it is so. Casing has seen its day; it has been a very good servant to us while we had nothing better, but really the time has come when we must go in for something more mechanical, and something less liable to create electrolytic leakage bridges between the wires. Mr. Crompton.

Mr. JAMES SHEPPARD [*communicated*]: Statements contained in the papers on electric wiring, with remarks made during the recent discussions thereon, go to show that a great change has come over the minds of electrical engineers with regard to the fire risks involved in their industry. Only a few years since it was usual for electrical engineers to assert that by the general introduction of electric lighting the number of fires in buildings would be greatly reduced. Mr. Sheppard.

This view was taken by the chairman of the London County Council in his annual address delivered on 26th July, 1892, in which he calls upon the fire offices to lower their charges to meet a promised reduction of risk resulting, amongst other things, from the introduction of electric lighting.

The fire offices favourably considered these promises, being always prepared to make a reduction of rates on good and sufficient reasons being shown—reasons that will bear the test of solid fact and hard cash, upon which alone the fire offices take their stand.

Mr. Sheppard.

The anticipations of the electrical engineers have not, unfortunately, been realised, and their confident attitude is not now assumed; but in its place round abuse and ridicule of the fire offices is indulged in, apparently because the offices very properly object to use their funds for the special protection and encouragement of electrical industries, and for the prevention of competition amongst "wiring firms."

As a humble Associate I submit that such action is unworthy of members of the Institution of Electrical Engineers.

That the introduction of the electric light has not reduced fire risks is shown by the number of fires included in the returns of the Metropolitan Fire Brigade, and especially by the fires that have occurred during the last 15 years in the following streets:—Cheapside, St. Paul's Church Yard, Ludgate Hill, Fleet Street, Strand, Charing Cross, Cockspur Street, Pall Mall, Waterloo Place, Regent Street, Oxford Street, New Oxford Street, High Holborn, Holborn, Holborn Viaduct, and Newgate Street. In the buildings lining these streets the use of electric light for the past three years has been more general and extensive than in any other part of London.

The number of risks in these streets has not changed, while their general character has been much improved; yet since the introduction of electric light the number of fires has increased 25 per cent., as the following figures, taken from the daily returns of the Metropolitan Fire Brigade, will show:—

Number of fires in the streets above named during five years,	1881 to 1885	185
" " "	1886 " 1890	186
" " "	1891 " 1895	231

These "solid facts" indicate that, while electrical installations have introduced special risks of their own, they have in no way reduced the general risks attached to business and other premises. This is only what may be reasonably expected, because electric light is not provided for every dark cupboard, or for rooms seldom used, and it is in such places that fires occur from the occasional use of artificial light.

Only recently about 20 fires have occurred in private

dwellings in Hamburg caused by the current used to work the tramways finding its way into the electric light mains. Mr Sheppard.

Experience also with regard to the fire risks of electric generating and distributing stations has not been encouraging, and the numerous explosions in inspection and junction boxes for electric mains in the public streets are somewhat alarming.

Disasters of this kind are likely to recur, more especially if electrical engineers disregard the teachings of experience, as shown in one of the largest and newest supply stations in London, where to the risk of high-speed electrical machinery, switches, and other appliances, there has been deliberately added all the risks of a dry and fiery coal mine.

Fire offices cannot do more than select their risks with the object of excluding those that fail to come up to a fair average standard in their respective classes. In this process of selection many other, and in most cases more important, questions than that of artificial lighting, require consideration.

If over a series of years, experience shows that the rates usually charged are insufficient, they will undoubtedly be increased; while competition, to which fire offices are subjected equally with wiring firms, will inevitably bring about reduction of rates when this can be reasonably conceded.

The only possible way by which fire insurance premiums can be permanently reduced is by the reduction of losses by fire, and before electrical engineers can secure the advantage of low fire insurance rates they must show definitely and conclusively that the number of fires from every cause are less frequent in premises using electric currents than in similar premises where electricity is not used.

Mr. Fred. H. Taylor [*communicated*]: The authors of the two papers we have before us for discussion to-night are to be congratulated on having brought before this Institution a subject so deserving of the individual attention of almost every member of the electrical profession. With reference to Mr. Bathurst's remark that "fire office rules have been administered under "indefatigable and impartial inspectors," my own experience leads me to the conclusion that the average fire insurance inspector is Mr. Taylor.

Mr. Taylor. a mere ornament, and practically of no use whatever. He should at least be a man thoroughly well informed of his subject, up to date, and capable of discriminating between what is really *bad* work and what is really *good* work. It is also but little use for any inspector to view the installation when it is completed, and all the hideous iniquity (now so prevalent) is concealed beneath floors, or at least covered in with capping.

I think we are all of us agreed that the state of affairs with wiring contractors is "bitterly disappointing." It is peculiarly so to any *bonâ fide* electrical engineer who is engaged in this class of work for a livelihood. A "wiring contractor" may now be anyone qualified or otherwise—usually otherwise—and frequently a "jerry "builder," bell-hanger, or plumber, with little means and less knowledge of the industry he is spoiling. It seems to me it must rest largely with the public themselves, aided by capable inspectors, to put a stop to this system of cheap and worthless wiring work.

In any conduit system using an insulating tube we have, *it seems to me, a solution of many, if not all, of our wiring weaknesses.* It is not metallic, and, Mr. Bathurst assures us, is a bad conductor of heat, and therefore will not readily sweat internally. In practised hands, it must undoubtedly involve far less labour in the fixing up than the existing system of wood casing, and it therefore will, as its use becomes general, considerably cheapen the work of wiring.

Any conduit system clearly involves to a greater extent the system of running back to common "centres of distribution."

This, in all fairly large installations, is not only advisable, but should be compulsory; and with a conduit system, what joints there are, are situated in the junction boxes, and are, therefore, open to inspection.

I quite agree with the author that both wires should be run in the same tube. I see no objection on the score of insulation; at present ordinary wires (and even flexible cord) are allowed to be drawn through brass or iron fittings without any additional protection whatever, although it is held to be very wicked to run wires of opposite polarity in the same groove of wood casing.

Though it has not been my pleasure to have had practical

experience with this system, it appears to me to be the solution Mr. Taylor. to the numberless difficulties referable to wood casing, and in the hands of capable electrical engineers undoubtedly has an extensive field of usefulness before it.

Mr. W. HOWARD TASKER [*communicated*]: It appears to me Mr. Tasker that the authors of the papers under discussion have been ill-advised in making such a vigorous onslaught upon "wood casing," in the hope of raising their respective banners to the coveted position.

If the authors had been content to offer their useful aid in pressing before the Institution the several advantages of their own methods in fulfilling some of the complex conditions obtaining in fitting buildings for electric light, we should have had nothing to say, on this head, further than an expression of gratitude for additional help.

It certainly should not be allowed to go from this Institution that "wood casing" is generally acknowledged to be either an unsuitable or an expensive method of "wiring." In surface work it is admirably adapted to the architectural requirements of highly decorative work, not alone in old buildings, but in the modern ornate styles of house fitting. Even in the many instances where concealed work is necessary, it is an invaluable tool in the hands of the experienced.

"Wood casing" may be an *ancient* fortress, but it is thoroughly capable in its own defence. There is often some weak point in every stronghold. I trust the authors will be content to cover with their modern improvements any weak spots that may occur in this stronghold, rather than attempt to explode the fortress.

I cannot agree with Mr. Bathurst that his insulating tube method will prove the ultimate solution of the electric wiring question, though it appears to be a useful adjunct. Mr. Bathurst advocates a single insulating tube with two insulated conductors; and, bearing in mind the insulating properties of his tube, he would use less expensive conductors by robbing them of some of their insulation. I must say I should not feel happy in trusting to the insulating properties of the tube on considering the number

Mr. Tasker of joints that would be required in a building, and the numerous breaks for the accessories.

In paragraph 2, page 4, Mr. Bathurst explains why two insulated conductors should not be placed in a metal tube; and later on we find that he advocates placing two conductors in his insulating tube, covered with iron or steel. Perhaps Mr. Bathurst will make it more clear what he means, as one statement appears to contradict the other.

I am glad Mr. Bathurst has provided us with an antidote to *rats*, though personally I have not been troubled by their depredations.

The main contention in both papers—if I mistake not—is for a simplification of the wiring question by reduction of first costs of fixing up, so as to bring the fitting of buildings within reach of the majority of would-be consumers. I fail to follow the authors in believing their methods will do so. At the same time I thoroughly appreciate the mechanical completeness of Mr. Mavor's method.

A lengthy experience of conduits for the distribution of electricity under ground, and the admirable facilities obtained by a drawing-in system—not alone being the avoidance of disturbing streets after first placing—compels me to favour an extension of the idea for interior use.

Coming more particularly to Mr. Mavor's paper: I thoroughly associate myself with Mr. Mavor in his strictures upon the indiscriminate use of *fuses*. Fuses should be grouped at convenient centres on "distribution boards," guarding circuits of small and equal loads; and joints on the "runs" should be avoided.

There can be no question as to the valuable water-proof property of concentric wiring, and for mines, mills, ships, isolated installations, and in buildings where dampness prevails it must take a leading part; but I do not like the thought of his armour-clad methods in drawing-rooms.

I feel sure the Institution, in the ideal standard which we understand the committee are proposing to erect, will draw up the rules in such a way as to leave the authors' methods admissible; and any other methods that may germinate from experience.

With reference to a remark which Mr. Geipel made during the discussion at the last meeting anent the use of the Edison screw socket lamp-holder, which he considered was a better holder than the bayonet socket, my experience is that the Edison screw socket holder is useless where there is any chance of vibration, as vibration causes the contact to loosen. This is probably one of the main reasons against its use in towns, where the buildings line the thoroughfares along which the supply mains pass. Mr. Task

There can be no question as to the adverse circumstances created by the rush of inexperienced men and tradesmen into the industry. The whole of the industry is most prejudicially affected thereby; and the time has come when the Institution should face the fact, and use its power to curb and direct the future.

The carpenter-wireman is an experienced, reliable workman; and why should such men be indiscriminately engaged in common with men whose only claim to a knowledge of electric wiring is the fact, or fiction, that they have fixed bell wires? Experienced men will not retain interest in their work when they find any class of work will do. Why not employ some method of registration, and grant certificates, bearing the authority of this Institution, to the men who are properly qualified? Some such method, I understand, obtains with the plumbers. Why not with wiremen?

On the question of a thorough inspection of buildings during the fixing of electric light wires by a fully qualified and independent electrical engineer—which is the only way to prevent undue competition and shoddy work—there are two parties concerned, viz., the *supply authorities* and the *insurance companies.*

Now it is quite unreasonable to expect the hard-worked central station engineer to undertake that duty, with his hands already full, and no monetary compensation. Moreover, should this additional burden be put upon him, his position would be intolerable, as members of a Corporation in the provinces are oftentimes the very men who wish to embark upon electric light wiring (coupled to their own business), and a disagreeable situation for the central station engineer might reasonably be anticipated.

Mr. Tasker I also very much doubt whether the insurance companies will come forward with properly qualified electrical engineers for each centre of supply.

I would venture to suggest that some compromise might be made by appointing qualified engineers for large towns or districts upon the basis which holds under the Building Act, viz., the office of district surveyors, whose qualifications for the appointment are first attested by the Royal Institute of British Architects.

The Institution of Electrical Engineers might certify qualified engineers for district surveyorships, and it should be in touch with the local authorities. The local authorities, or county councils, in a large town or district respectively, to appoint such independent and qualified electrical surveyors to act for them. The insurance companies might possibly avail themselves of the services of such men to be their district representative inspectors.

If the Institution took such steps as have been foreshadowed in this discussion, and can bring to the knowledge of local authorities the Institution's "standard of wiring," suggesting some such way of getting the rules carried out, as circumstances permit, much of the discontent in the industry would, I fancy, disappear, and we, as members of the Institution, would remain proud of our officers, and glad of our corporate existence.

Mr. Snell. Mr. ALBION T. SNELL [*communicated*]: Most of us are agreed that it is desirable to alter the present system of wiring in wood casing, which is often ugly and generally unsatisfactory from an engineering point of view. Yet it must be borne in mind that the question of cost is the most powerful factor in the problem.

The chief objections to wood casing are the number of small parts incidental to the system, and the general want of mechanical stability. These defects are now well recognised, and it is the practice of the best engineers to advise the use of metal pipes or of armoured concentric cables where the conditions are unfavourable to the use of wood casing—in such places, for instance, as breweries, basements, mills, and factories.

It has been claimed that interior conduits and concentric

wiring are cheaper to instal than wood casing. This, I think, remains to be proved; although it may be so in the future, when things are more settled, methods have become better understood, and parts are standardised on lines similar to gas fittings. Mr. Snell.

I have used a large quantity of iron barrel of late, some of which has been in use for eight years. In a recent installation for which I was responsible there were used over 5,000 feet of iron pipe of various sizes. The plant has now been running for about 15 months, and the insulation resistance was higher when I tested it last December than when the wiring was first erected. The pipes are ordinary gas barrel, reamed out, and painted inside and out before erection. The cables are insulated with vulcanised rubber, and have an insulation resistance of not less than 750 megohms per mile. The iron pipes are screwed into junctions at the distribution boards, and every ceiling rose and separate switch has an iron box around it, so that from the main switchboard to the ceiling roses the system is enclosed in iron. I issued specifications to six of the leading firms of contractors who had had experience of iron barrel work, with the result that the average price of the tenders was rather higher than that required by the same firms for wood casing work.

Unarmoured interior conduits are, in my opinion, superior in many respects to wood casing; but they, in common with wood casing, are likely to cause trouble from fire in the event of moisture getting to them. We have had no experience on this matter in England worth relying upon; but in America much experience has been gained in the use of interior conduits, both armoured and plain. I find, on consulting the Electric Fire Rules of the Inspection Department of the Associated Mutual Fire Insurance Companies of Boston, dated March, 1895, the following rules, which may help to throw some light on the matter:—

"1. That tubes or conduits are to be considered merely as "race-ways, and not to be relied upon as insulation "between wire and wire, or between wire and ground.

"2. That both plain and brass armoured conduits are not "deemed sufficient to resist destruction from an arc— "forming between two wires in the same conduit—

Mr. Snell.

"and that therefore only one wire in a conduit is "allowed.

"3. When heavy iron barrel is used (plain or insulated), that "two wires—or three wires on a three-wire system— "may be drawn into the same tube.

"4. That the mass of iron in a heavy iron tube heats slowly "and tends to cool down the arc—forming between "wires in conduit—and prevents it causing heating "until the fuses let go and cut off the current."

From these extracts it would appear that interior conduits are no safer from fire than wood casing, and, in fact, require the same precautions as regards the separation of the wires. Also, experience points to the use of stout metal pipes as the safest possible form of conduit. And, further, since conduits are not regarded as insulation between the wire and ground, that there is no special advantage in insulating the interior of the tubes. In fact, the insulation should be on the wires themselves, and not on the conduits. Of course it is advisable to bush the mouth of iron tubes at the distribution and drawing-in boxes, so as to avoid damage to the covering of the wire.

It has been urged that metal pipes are likely to sweat, and thus cause trouble from rust destroying the insulation. I have not found this to be so, but I can see the possibility. Perhaps I owe immunity to my practice of painting the insides of the tubes. In places where there is probability of condensation I prefer to use concentric lead-covered cables.

A conduit system is said to offer facilities for withdrawing wires for examination. This may be so sometimes, no doubt; but as a rule I assume it to be by no means désirable to interfere with the wiring, because of the chance of damaging the rubber.

There is a simplicity about concentric wiring which commends it to all engineers, and it is to be regretted that the Board of Trade Regulations do not permit of its general use on premises of consumers supplied direct from central stations. Such a system gives, at least, as much protection from fire as any other, for it may be made both water- and fire-proof, like stout iron barrel;

and it has the advantage of lessening the number of fuses and main switches by one-half. Mr. Snell.

Mr. S. Mavor, in my opinion, has *not* exaggerated the safety of concentric wiring when he says that "a short-circuit in a "concentric main must burn out the controlling fuse." I do not see how it can fail to do so, and that quickly, too, because the intensity of the leak between the two wires is continually increasing, and must result in a complete short-circuit if the fuse does not go. Experience shows, however, that a burn-out in an iron tube may melt a hole in the iron, especially if the fuse be defective and the pressure of supply be high. I have recently seen a piece cut out of a large concentric feeder encased in iron tube about a quarter of an inch thick in which a short-circuit between the inner and outer conductors burnt a half-inch hole through the iron. The pressure was about 2,000 alternating volts, and the power available was certainly 400,000 watts. In houses there is much less chance of damaging iron pipes, since the pressure is usually limited to about 110 volts, and the power in any one circuit is comparatively small.

For mining work, in most cases, there is no form of cable to compare with a concentric one, and I have used the type largely.

Now, is it possible that the cost of wiring can be reduced? Present prices are too high, and yet they often are unremunerative. But this is chiefly owing to want of uniformity of practice, and the fact that many contractors make their own details instead of buying standard types of large manufacturing companies. The attempts made by the exponents of concentric wiring to standardise the details of the system are deserving of the best thanks of both the profession and the public, for they all make for cheapness without lowering the quality of the work. I think we must look to some development of concentric wiring to solve the problem of a cheap and safe standard system.

Comparing wood casing, interior conduits, and concentric wiring, each seems to have certain advantages; but it appears to be more than probable that the use of 220-volt lamps will tend to discourage the use of wood casing. Interior conduits, when built up of iron tubes, are specially suitable for use in new buildings,

Mr. Snell. and concentric wiring has a large future before it when the Board of Trade restrictions are modified.

Mr. Chamen. Mr. W. A. Chamen [*communicated*]: I have had some experience of Mr. Mavor's system of C.C. wiring, extending over the last four years, having carried out some eight or ten installations with it, amounting to an approximate total of 1,300 incandescent lamps. These installations comprise factories, pottery works, private houses, places of amusement, laundries, and even gas works. In one installation the wires and cables were armoured throughout, but in the others this has not been done. The objection has been raised by some speakers that nails can be driven into C.C. wire, causing short-circuits. Of course nails can also be driven through wood casing just as easily, but they may not in that case directly cause a short-circuit. It appears to me, however, that the damage caused by a nail SHOULD develop immediately into a short-circuit, causing the cut-out to fuse, and making it absolutely necessary to set matters right before the lights can again be started. In all probability more electric fires occur through leakages (in installations carried out on the ordinary two-wire system) than through short-circuits. In the C.C. system it appears to me to be practically impossible to cause a fire in this way. Any leakage is of necessity internal, and cannot start combustion outside the conductor. If the cable is armoured, it cannot be damaged by nails.

Again, the system is one which may be regarded as absolutely water-tight, so that it is particularly fitted for damp places.

I have used the system with great caution, going on step by step, but in every case I have been perfectly satisfied with the results obtained.

No doubt improvements may be made in details from time to time, but the system as it stands is already complete and easy to use. The fact that one can do away almost entirely with carpenters is a very great point also in its favour. If this system of wiring could be generally introduced, the fitting up of houses with electric light would become work for plumbers and gas-fitters rather than for carpenters and so-called wiremen.

The system generally has given such complete satisfaction that it is much to be regretted that it cannot be used universally in connection with all central station supplies. With alternating-current supplies, of course, it is an easy matter to arrange this by means of transformers, as has already been suggested; but in low-tension continuous-current three-wire networks—unless the middle wire is earthed—it is of course impossible to use it. The recent decision of the Board of Trade to allow the middle wire to be earthed removes the difficulty to a large extent, but it is still feared by many engineers that there will be a sufficient difference of potential between various houses on such a network as to cause some little trouble by electrolysis. I do not think that this trouble will prove a real one. All our experiences of electrolytic troubles are in cases where the leakage current is one of considerable difference of potential at the points of leakage; but on the middle wire of a three-wire system there can be no differences of potential between the most remote parts of the network unless the two sides are out of balance, and even in that case these differences must be very small. If the Board of Trade will allow earthing of the middle wire, say at *all* feeding points instead of at the generating station, I do not think there will be any trouble at all. Mr. Chamen.

Mr. KENNETH J. TARRANT [*communicated*]: As having the honour to represent one of those much-abused institutions, the fire insurance offices of London, there are one or two points in connection with the two very valuable papers on the electric wiring question by Messrs. Bathurst and Mavor which I think are worth calling attention to. At the outset, however, it must be remembered that the purely electrical view of an installation, and the same considered from an insurance standpoint (as regards fire risk), are two very different things; and hence I do not think it is possible for any insurance inspector to lay down any hard-and-fast line as regards this or that system of wiring. The first point that has struck me in reading the two papers is that the writers are, perhaps, too severe in their strictures as regards wood casing, and do not refer to the great amount of excellent work that has been done on the two-wire system in Mr. Tarrant.

Mr. Tarrant.

this very way; many of which installations are running as well at the present day as when put up some five or six years ago. At the same time, it is useless to ignore the fact that wood casing is worse than useless under certain conditions, and hence I think that the conduit system introduced by Mr. Bathurst is unquestionably a step in the right direction. From a series of experiments with the tubes on my own installation (only 50 volts, it is true, off accumulators), I find, first, that it is practically impermeable to wet; second, that it is very difficult to fire it by any ordinary electrical mishap. Of course it will burn if put in the fire, but the only way I have been able to actually fire it is by starting an arc between two carbons inside the tube and allowing it to burn itself out; under these circumstances wood casing would have done no better, to say the least of it. As regards the objection that has, I believe, been taken that nails can be driven through it, surely the same applies to wood casing, compo tubing, or anything short of iron gas barrel, which latter system of wiring certainly embodies the several defects mentioned in Mr. Bathurst's paper.

Turning to the concentric system, I must say that from a fire point of view it is very good; but, unfortunately, every system on this principle with which I am acquainted compels the use of certain special fittings, and hence is not applicable in the general sense. The worst feature, is undoubtedly, that it is of course absolutely inadmissible on continuous mains, owing to the earthed outer; hence its use is practically restricted to plant installations and alternating circuits (with an equalising transformer if supplied from a sub-station). With regard to the fusing question, I am quite sure that an installation may be *over-fused* as well as *under-fused*. An unnecessary multiplication of fuses only lowers the insulation resistance of the whole without any corresponding advantage; hence, if the installation is divided into small circuits, to put in a fuse at every change of section in the wiring appears to be worse than useless. At the same time, flexibles should be protected, and it should not be possible to find (as I have recently) a 35/40 flexible protected by a 40-ampere fuse. What is wanted appears to me

to be, first, a fuse fitting that shall not lend itself to the introduction of any substance other than fuse wire, if the latter is not handy when the fuse goes (this is met in the C.C. concentric system); and, secondly, some system of wiring in which the potential strain is contained in the cable, but which (until the day when earthing is allowed by the Board of Trade) has both poles insulated, while at the same time it is applicable to ordinary fittings. Mr. Tarrant.

In conclusion, there is one point in connection with installation work which I trust I may touch upon, viz., that I fear insurance companies pay far more attention to the insulation test than the quality of the work. Of course a good test between poles and to earth is all right from a supply point, but it does not show defective jointing, or, if the place is dry, inferior wiring; nor do I see how these *are* to be discovered, for unsoldered joints and bare copper in a dry situation would give a fair result. My own idea of wiring is to wire with insulated cable on insulators, so as to get air insulation wherever practicable, have all joints in view, and work on the distribution system in fairly small circuits throughout. Of one thing I feel sure—that it is to the advantage of the insurance companies to keep in touch with the electrical engineers, and, when a difficulty arises, to endeavour to settle it on a basis satisfactory to both.

Mr. P. I. UNWIN (of Elliott's Metal Co., Ltd., Birmingham) [*communicated*]: I have read with much interest Mr. Mavor's paper on his system of wiring, and, having had practical experience of the same on a rather large scale, possibly this may be of interest to the meeting. Nearly two years ago a lighting plant was put down at these works, which are chiefly rolling mills, consisting of lights equivalent to about 5,000 8-candle-power lamps, partly arcs, partly 150-candle-power incandescents, and partly small incandescents. The whole of this system, which covers about four miles of wiring, ramifying in all directions over 6 acres of ground, was carried out on the concentric system; the mains being underground throughout, and branches overhead in the various mills. No casing has been used in any part, the wires being strung along tie rods and cleated Mr. Unwin.

Mr. Unwin. up like gas pipe. During nearly two years' experience of this installation, not the slightest hitch or interruption to the working has been occasioned at any time by defects in the wiring or mains, and the insulation resistance is as high as when the plant was first started. Slight defects have occurred in electroliers not supplied by Messrs. Mavor & Coulson.

I do not hold a brief for the system, and have no connection with it in any way, excepting that it appeals to me, as a mechanical engineer, as a first-class engineering device; but I have no doubt that, if it were more generally adopted in the electrical trades, danger from fire and partial short-circuits would be a thing of the past, and that the era of the "jerry" wiring contractor would receive the most serious blow to its prosperity that could well be devised. It is not necessary to enlarge upon the resultant advantages to electrical engineers, and to the trade as a whole, which would naturally follow in the steps of the abolition or decrease of "jerry" wiring.

It may seem audacious to say that short-circuits cannot occur in a wiring system, either partially or otherwise, but I am able to fully confirm Mr. Mavor in this respect. If any short does occur, the fuse protecting the line in question blows at once; defective fittings have caused this occasionally in these works, but never defective wiring. Finally, I trust the day may not be far distant when the Board of Trade may see their way to permit a system with one side earthed to come into more general use. But even now any engineer interested in works or ship lighting might make himself fully conversant with the details of the concentric system.

Mr. Bathurst. Mr. F. Bathurst, in reply, said: Owing to the discussion having been more upon the general considerations governing the question of wiring than upon the particular points advanced in the papers read, I would ask to be excused from taking the criticisms *seriatim*, and be allowed to reply to the various points raised as they fall in place from a reconsideration of my paper. Those who have taken part in the discussion seem to have left our points—or, if I may speak in metaphor, our "fangs"—severely alone, perhaps under the impression that Mr. Mavor and myself would ultimately settle

our particular differences and become as of one mind, in accordance with the fashion recently set for us by the two boa constrictors in the Zoological Gardens. The incident I refer to is probably still within remembrance. An analysis of the criticism will show that the *economical* rather than the technical side of the question has been taken throughout. Starting with my five cardinal points for good wiring—safety, durability, convenience, accessibility, and economy—although convenience has, in some small measure, been touched upon, the two last points are the only ones that really stand questioned. Mr. Bathurst.

Taking accessibility first, perhaps the main criticisms are at once removed when I state that I use this word mainly in the sense of *reliability*. Conductors are not to be pulled in and out except in the case of mishap (and no one surely can gainsay the fact that electric wiring of all kinds *is* exposed to trouble); and I maintain that it is a factor of great reliance, and even of paramount importance, to feel that *it is possible* to remove or replace electric conductors without any disturbance of their surroundings. It was Mr. Corlett, I think, who said he thought there was a great deal of unnecessary prejudice shown about burying wood-cased enclosed wires directly in plaster, and argued that we had never yet heard of householders complaining of the "inaccessibility" of their gas pipes! Perhaps not, but I think his point fails in application. A gas pipe under ordinary conditions will not allow more than a certain quantity of gas to pass through it, and no matter how many burners you put on to it, or other orifices which are made, the flow of gas can never damage the pipe. To compare an insulated wire with a gas pipe, the thin insulating coat represents *the pipe* itself, whilst the copper conductor represents the *orifice*. This kind of "orifice" will carry as much current as you will give it, and with immediate injury to the insulating sheath or "pipe." In fact, it is a simple matter to destroy both. If gas pipes had an unfortunate facility for "leaking" or "bursting" upon the slightest provocation—say upon the appearance of moisture, or an unanticipated extra consumption—should we not have complaints? Would not every gas pipe *have* to be accessible? The conditions governing gas piping and electric wiring are in this particular diametrically opposed.

Mr. Bathurst.

Several speakers have intimated the necessity of watching and controlling the work of irresponsible workmen or contractors: have any suggested a "check" which is more legitimate or satisfactory than "accessibility"?

From the other point of view, the growth of electrical application is so rapid, and, so far, almost untouched, that if we are to recognise the demand of our supply stations for a "day load," and have any regard for the convenience as well as the pockets of our customers, we ought to give them "accessible" wiring, so that any possible and legitimate requirements can be met, and later alterations effected with a minimum of trouble, inconvenience, and expense.

I submit my point that every electric conductor in house-wiring should advisably be "accessible."

Turning to "economy," this is really the crux of the whole question, and is the *dæmon* I shall struggle with.

It appears at least to be tacitly admitted that wood casing is technically wrong and undesirable, although its cheapness and ready convenience is, in some quarters, considered to outweigh its immediate or prospective disadvantages. As I have tried to point out the technical defects incident to its use and employment, those "conservatives" who still pin their faith to it have questioned "conduit methods" on the score of economy. I will try and rebut their statements.

These critics all admit the mischievous and harmful commercial conditions now obtaining in the electric wiring industry, and, in face of the complaints rife from every section of it, they could indeed hardly do otherwise. I believe we have reached the turning-point when inquiry into our present methods *must* and *will* be made; for, in spite of an enlarging commercial field, it can almost be said that no one is deriving any benefit.

The wireman complains that he cannot make a "living wage," and is being ousted by inferior workmen; wood-casing manufacturers say they make casing without profit, and simply in order to keep their moulding machines full of work; the porcelain manufacturers are combining in an endeavour to keep up even present prices; whilst the sum-total effect is being most seriously

felt by the electrical supply houses, who are asked to make cheaper fittings and extend longer credit. These conditions *must* be faced and a solution found. I contend that the *principle* we have heretofore been working upon is incorrect. We have been using wood casing and metal pipes, and, by so doing, have not only introduced unnecessary difficulties and troubles, but have crippled ourselves commercially. For want of any suitable protecting medium we have had to adhere to highly insulated, costly, and expensive wire (rightly, perhaps, so far); but, as a principle, we have insisted upon having electric conductors insulated so that they could practically look after themselves, without receiving anything beyond a slight mechanical protection from the supporting or surrounding medium. We have now nearly exhausted the demand for wiring which comes from those who are willing to pay any price they are asked, and are beginning to feel the pinch and necessity of "lower cost" wiring. I hold that wood casing or ordinary metallic piping is impotent to meet these conditions. Take the cost per point to a contractor for wiring a certain building as, say, 10s. per point (this is for the wiring only, without fittings), the analysis of this cost will probably be, approximately— Mr. Bathurst.

1s. 6d. for wood casing and accessories;
4s. 6d. for wire and jointing material;
4s. 0d. for labour of erection.

Casing is the lowest item, whilst labour and wire come out about equal. My contention is that it is advantageous to the contractor to employ methods which will reduce the *labour* item, and perhaps also the *wire* item, even if the other one remaining—"casing," or other supporting material—is thereby increased. If using the plain insulating conduit now before you, the above work will cost, say—

3s. for insulating tubing and accessories;
3s. for wire; and from
2s. to 3s. for labour of erection.

The special twin wire to be used is listed at prices 25 per cent. lower than the ordinary 400-megohm quality, and contractors can testify to the satisfaction it gives, and the labour-saving

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possibility of conduit methods. I am speaking from what has already been done, and stand by the statement that contractors can buy plain tubing and special twin conductor wire together at the same cost as ordinary wire, so that the cost of wood casing is entirely saved.

Technically considered, wiring of this nature must, on fair examination, admittedly be, at all points, *superior* to that employing wood casing; practically, it has distinctly proved itself so in other countries, and it is making its reputation in England. I will at this point, and for the moment, admit the criticism which can be made that this tube is not "nail-proof," and that specially insulated wire is employed. The principle followed, however, is that of insulating conductors sufficiently to look after the voltage upon them, and providing for their protection a *better and more complete* surrounding material.

Mr. Rawlings has suggested that the plain insulating tube should be flexible. I cannot agree with him, because my experience dictates that, for ordinary wiring at least, a rigid conduit is preferable. There are exceptional cases where "flexibility" can save labour and cutting away, but even this advantage is doubtful, for "accessibility" is lost. I can conceive no conduit which is "flexible," nail- and water-proof, and insulating. The nearest approach is the flexible hose used in steam-fitting work, and which is designed to work with a pressure inside. Setting aside the consideration of cost, and other disadvantages, the problem is how to make a flexible conduit nail-proof. This requirement seems to indicate that the material should be *as hard as iron*, which, again, is incompatible with any great degree of flexibility.

Several speakers advocate that *iron piping* is preferable to wood casing from the fact that it affords better mechanical protection. I was glad to hear one engineer at least—Mr. Campbell Swinton—say his experience made him believe that iron piping led to as much, and even worse trouble, electrically, than wood casing. Many well-known contractors have personally told me of the troubles they have already experienced with iron pipe: some of these faults are caused electrolytically; others,

of the damage done to the rubber insulating material on the conductors by excess of oil used when screwing up the couplings of pipe length; others, of mechanical injury to wires whilst being drawn in; but, strange to say, they have in this room, before their brother contractors, preferred to remain silent. Surely it is better to face the question here, and find solution, rather than wait until the public themselves decide whether or no there is cause to find fault with it, or that it creates a "danger" aspect? I must again, perhaps, be content to wait until *time* shall prove my contentions technically. Economically, however, they have no ground to stand upon; they cannot, if following their present lines, give a system of iron piping with two, or even one insulated copper wire inside it, and compete in price with ordinary gas piping. Mr. Bathurst.

Although it may appear paradoxical, this *can* be achieved with an insulating tube system, and even if this tube has to be *iron-armoured* throughout its length.

Whilst one or two speakers have doubted the necessity of placing an interior insulation on the inside of an iron pipe, and for the moment disregarding the obvious reasons which must sanction such practice, none of them have attempted to refute its advisability on technical grounds (it may be necessary to except Mr Dykes, who was coming to this point when the time-closure cut short his remarks); so we can take it that, if it is doing no actual good there, it is at least doing no harm. The main fault in their eyes is that it adds extra cost. It will be allowed that a lining prevents mechanical damage to the wire, and increases the facility with which wires can be drawn in. It prevents internal condensation, and so obviates the presence of moisture and consequent rust. It *must*, therefore, tend to preserve the conductors under more favourable conditions. The insulating coating being under the iron pipe is not liable to any chance mechanical injury, and therefore some sort and thickness of insulation can always be depended upon. In other words, insulation *is* added to the conductors. Does not this fact of being able to preserve some insulating material intact under all circumstances tell against those who advocate a very high

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insulation on the wire itself? I say this in spite of Professor Ayrton's predilection. These same advocates will not gainsay the statement that the wireman's boot can in a moment make away with any number of "megohms" asserted for the quality of the wire, whilst it is being put up.

My statement as to the actual insulation this particular interior lining *does give* to conductors within it, and the voltage it can stand without breaking down, as well as its shielding and subduing effect in the case of a short-circuit, I can only accentuate by asking those interested to verify by test. Two million lamps are making this test in other countries. So much for technical reasons for advocating insulated iron pipes.

If economy is sought, the co-operation of the wire manufacturer must be invited. Without arguing the fact that the present quality wire has primarily been designed to look after itself, and that instances have been given by which its possibilities in this respect can be proved, and admitting that the present type of insulated wire is as near the margin of efficiency as it should be, consistently for present methods, it can be urged that other types can, and should, be found.

Have those who cry out against permitting lower insulation wires ever considered their own practice? Have these critics ever protested against the use of the ordinary flexible cord? The insulation test on this (excepting the vulcanised variety) could not be taken in water, and probably gives 300 megohms in open-air conditions. The insulating medium is a thin strip of pure rubber secured by a cotton covering. Oftentimes the rubber is a covering only in name. Yet experience surely sanctions its use, and admits its convenience and economy. Do these critics remonstrate because they find commercial exigencies make it convenient to put further trial on this thin insulation by hanging a three- or four-pound weight at the end of each cord in the shape of lamp-holder and shade? What do they say to its further aggravation by passing it over a number of friction pulleys in adjustable fittings? The present stress of competition is noticeably increasing the amount of flexible cord being used, and my critics must notice that single lamps are rapidly changing into

three- or four-light clusters. The development of this practice may not prove that it is right, or even desirable, but I maintain it *does* point to the possibility of getting away from the "megohm" variety of wire. What harm, I ask, can result, even if wires of no better insulation are installed in an armoured insulating tube which can look after them mechanically and electrically, and in which any short-circuit it is possible to make under practical conditions is rendered innocuous? Insulated wires less costly, but equally as serviceable and effective when in protecting tubes, can, I assert, be produced. Have a good and serviceable insulation, by all means; but the question which should be settled, perhaps with wire manufacturers, insurance men, and wiring contractors in joint conference, IS, Where is the *mean* which meets the requirement of efficiency with the commercial demand for economy? Safety, I am convinced, is the least question, because it can be provided for by using an insulating tube. Mr. Bathurst.

Once this question of wire is settled, we see the gain of further advantages from conduit methods. A small twin conductor is employed which requires a tube of smaller orifice for the conveyance of electricity than is required for the conveyance of gas, taking light for light capacity. An armoured insulating tube creates the possibility of a large labour-saving factor, for sliding couplings and cemented joints can be used, and will make a water-tight electric system. Screwed couplings are rendered necessary in *gas piping*, so as to successfully resist the internal pressure.

Working on centre of distribution methods we shall find that only $\frac{3}{8}$-inch and $\frac{5}{8}$-inch tubes need be used, for all twin conductors up to 5- or 6-ampere capacity will go into the former, and up to 10–12-ampere capacity in the latter. Sub-mains can feed from main fuse and distributing boards in $\frac{5}{8}$-inch, or perhaps 1-inch, tubes. The bugbear of wood casing—the difficulty of estimating labour—will be removed, because the conduit wiremen will put up tubes by contract per foot run, as is now being done with gas piping. Tenders for work will then become comparable with one another.

Mr. Geipel has rightly accentuated the importance of the

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outlet points; and all will, I think, admit the advantage of using a small insulating box, armoured where necessary, which is equally applicable either for jointing—although taped joints will be unnecessary—or for the insertion of branch connecting blocks, switches, wall plugs, and even ceiling roses. Mr. Wallis-Jones has rather taken the words out of my mouth when he said we had passed through a wood age, a stone or earthenware age, and were now in the insulated iron age. There is no need to employ the "little cheese-headed screws" so justly criticised by Mr. Mavor, but soldered or mechanical connections can be made as desired under screws, upon which the wireman will exert his strength and not his skill. I would also like to support Mr. Geipel in his statement, or in his belief, that the Edison lamp-holder is the best yet produced, both for socket and lamp; the vibration difficulty has been entirely overcome, and the holder satisfies every requirement. Possibly the present double-plunger type is the outcome of the patent exigencies of early days. If these papers do nothing else than indicate the necessity of standardising our present wiring appliances and accessories, they will, I hope, have served a useful mission, and place more suitable profits into the pockets of the wiring contractor. My belief is that we are already in a position to compete directly with the cost of gas piping. Electricians gained entire control of the electric bell and signal field because they found out how to compete directly with the other methods in the cost of installation. We shall control the lighting, heating, and power fields when we meet rival methods fairly in respect to the initial cost of installation.

"Insulating conduits" have prejudice to overcome, just as the other innovations of modern days. Take, for example, the "New "Woman." This comparison at first sight may appear long-drawn; but, looking closer at the phenomena, we find they are both intimations of changed economical conditions which necessitate a *scientific curtailment* of useful material; and, further, it is necessary to have an *effective* disposal of the material employed.

I quite admit that at present we are, as it were, only in the gun-barrel stage of early gas-fitting practice; but, gentlemen, the

demand, and consequent price, of insulating tubes depend upon you. It may be of interest for you to learn that, in spite of difficulty and opposition, the last nine months have not been wasted in respect to the particular system I advocate; for, thanks to the co-operation of the General Electric Company, we can estimate that some 25,000 incandescent lamps in England are already testing the merit of conduit methods. I have to thank Messrs. Christy Bros., Chelmsford; Page & Miles, Brighton; Mr. Barrett, Cambridge; and Messrs. Strode & Co., of London, as being prominent amongst contractors who have had the courage of their convictions in adopting this method of wiring; and Messrs. Kincaid, Waller, & Manville, and Mr. Geo. Wilkinson, amongst the consulting engineers who have advocated it. Mr Bathurst.

So far, I have dealt only with the criticisms made on my own paper; but, if not trying your patience too much, I would like to refer to points of resemblance and dissimilarity between Mr. Mavor's paper and my own.

First, then, as to the points on which our papers are agreed. I am at one with Mr. Mavor in his witty and amusingly incisive remarks as to—

1. The employment of wood casing.
2. The difficulties of the present-day contractor and wireman.
3. The inefficacy of present I.R. tests and insurance inspection.
4. The evils of indiscriminate fusing, and the value of working from "centres of distribution."
5. The room for improvement which exists in the detail of switches, cut-outs, &c.

1. I would wish to supersede wood casing even for ordinary work entirely. Perhaps it may be in some sense considered a technical triumph for English contractors to be able to point to present-day results, but wood-casing methods have never developed a complete system, and must always be uneconomical commercially. Time alone will show how far they merit continued confidence.

2. I would obviate the troubles of the present-day contractor by giving him a standardised system, and one for which sound

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and practical arguments can be advanced. This will give his wiremen plenty of work, because ultimately it will open up a field as extensive as gas piping. As the gasfitter finds his employment slipping away, I would wish to train him up to electric piping on conduit methods; and on this head I shall not clash with Mr. Mavor, who expresses a decided preference for the plumber. In America this change has already commenced, and the wireman gas-man is called in the vernacular the "Hoodoo "gas-man." I prefer him to Mr. Mavor's "Hindoo" tinsmith.

3. If I may again parody Mr. Mavor's words, I would overcome the shortcomings of I.R. tests by providing an "accessible" system which possesses an inherent insulation, existing under all conditions, and has the ability to defy the approach of the charwoman with her wash-bucket, the insidious action of a Scotch mist either in the tube or on the walls, the nail of the carpenter or amateur picture-hanger, the heel of the wireman's boot, or the playful experiments of a budding though perhaps too inquisitive electrician. Under these conditions insurance inspectors will be at a discount.

4. There is a noticeable similarity in the fuses and intersection box system of distributing both in concentric and conduit systems.

5. Our efforts are being concentrated on the improvement and standardisation of detail accessories, and we look for encouragement from all contractors, and the sympathy and approval of this Institution.

Coming now to the points on which he is open to challenge—and I am tender—on page 611 he says: "As far as he is aware, no "system of concentric wiring in which both inner and outer "conductor are insulated has ever been used for indoor work."

In his reply, he told me the outer conductor I showed in one of my illustrations is *eccentric*. Seven years ago we developed this method of placing one conductor around the other; but our experience convinced us that it offered no advantage over twin parallel, or separately insulated conductors, and entailed considerable difficulty and disadvantage in respect to jointing and connecting. I agree with him it was eccentric.

Again, on page 620, when quoting the difficulties the Admiralty have had with ordinary double wiring, he says that their comparative failure "admirably illustrates the difficulty of designing "water-proof fittings for use in a double-wire system where the two "sides of the circuit must be insulated from each other, and both "from the metal of the containing boxes." As this is exactly the problem we have overcome, I hope that the attention of the Admiralty will be called to my interior conduit system: we employ double wires, armoured insulating pipes, and boxes hermetically sealed throughout, and provide thereby electrical and mechanical protection "from switch-board to lamp-holder." In fact, I fear I must here challenge Mr. Mavor to show the superiority of the concentric system at any one point, mechanically, electrically, or commercially. Mr. Bathurst.

Again, Mr. Mavor vigorously attacks the old method of double wiring, and points out its faults, in order to prove the superiority of his system. If one has inclination, it is easy to take his own words on pages 608, 613, and 616, and put them together so as to prove that his lead-covered or wire-armoured concentric system is just as vulnerable on the very points he tries to make. I submit that they do not hold against an armoured conduit system.

The detail points he could be criticised upon are his armouring and his joints. Omitting all possibility of mechanical damage when he embeds his present wires directly in the wall, does he maintain that they are practically imperishable? If so, I fear time will show that air and moisture will produce sufficient natural corrosion, and correct his present feeling that his system is quite "ideal." It is also noteworthy that Mr. Mavor's co-concentric pioneer, Mr. Andrews, in the new system he is developing now makes a feature of a *complete* copper tube as the outer conductor.

Whilst I appreciate the ingenuity with which Mr. Mavor has worked out his metal joint, I consider that it is open to criticism at least from its electrical functions. Poor joints heat and cause trouble. Hitherto we have taught our wireman that he should never depend entirely upon "solder" for a jointing connection, even if he must occasionally use it as a fuse. He has been told

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to make a mechanical connection, and rely upon solder to make it air-tight. It seems to me that Mr. Mavor requires his solder to fill a current-carrying function. I understand he recommends that each of his joints should be tested after it is made; but I would like him to explain either that it is quite impossible to make a poor joint, or else point out how his test *must* show it up. My experience is that few men can use a soldering bolt or blow-lamp properly, or do so, even if they know how. With this idea in my mind, Mr. Mavor's joint appears both costly and inconvenient. Success may be obtained with experienced men, but the difficulty will be to train them, and feel certain of the ordinary careless man. At any rate, the simplest method of jointing will be preferred, and, given my choice of two evils, I would rather chance an ordinary mechanical connection under a screw head. I might be prepared to use one "lock-nut" with it if absolutely necessary!

To me it appears that Mr. Mavor takes what he wants to have recognised as "an iron chain," and asks his workmen to put any number of "string" links into it. The main objections I make to the concentric system he so admirably and forcibly advocates—and sooner or later these points will have to be fully discussed—are lack of accessibility, or, if you prefer, "reliability," and the grounding of the outer. Accessibility I have already accentuated, but I think conviction grows upon one the more the point is discussed. Mr. Mavor twits accessibility as a "relic of olden "days." It may be so, but there are many engineers who will cherish it for some time to come. I will not take his own words on pages 608 and 609 to prove its desirability in case of an accidental short-circuit, but leave it, with the suggestion that concentric conductors had better not be overloaded, and should be carefully removed from any chance or unexpected electrical and mechanical trials. I suggest that without accessibility the use of concentric wiring is foredoomed entirely to *surface work*, and even then will give only a predetermined and limited service, without *absolute* reliability.

As regards grounding the outer, this one question could be discussed with an evening to itself. Even admitting the

desirability of earthing the outer in street mains, personally I do not see the wisdom of enlarging the distributing network *ad infinitum* by including customers' premises. This end, I would rather suppose, should exist only with both wires insulated. The consumers' wires have to be installed under every kind of trial, contiguous with gas and water systems, and pass over steel girders and other metallic constructions. Would Mr. Mavor have all these "earthed" as well? as, if not, I fear hazardous conditions will arise. Mr. Bathurst.

The risk of electrolysis "may be greatly over-estimated," but the troubles referred to in America have, I am creditably informed, convinced the authorities that even one-thousandth of a volt difference of potential is too much, and means deterioration, if not destruction, to gas and water pipes and other metallic bodies in the vicinity. After listening to Mr. Mavor's eloquent exposition of the advantages of a "grounded outer," I *was* surprised when, on his last page, he suggested two simple remedies which *might* be adopted. I should like to have heard some discussion on this point, particularly when we have heard Mr. Andrews express his pet ideas, and we find the two champions at variance. Mr. Mavor seems to imply the necessity of keeping intact (by a protecting lead sheath) a *light insulation* over the whole length of the outer conductor, except at distant ends. This being so, I ask him, Why not keep a slightly heavier one, and, following Mr. Andrews's leadership, use an iron armour instead of a copper tube, and, having got so far, say that he should by preference put "two" insulated conductors inside it?

Mr. Crompton has eulogised Mr. Mavor's paper as indicating that we may tend towards a "concentric" method in which a single well-insulated conductor will be used in ordinary iron gas pipe. When this time approaches I shall endeavour to prove to him the fact that it would then be commercially advantageous to employ a *bare* conductor in an armoured insulating tube.

I owe an apology to Mr. Mavor for thus criticising his distinguishing points, but I would as readily acknowledge and praise the thoughtful care with which the details of a complete system have been worked out. He can endure this criticism from

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his rival, as everyone else has let him off so lightly; and, returning to my first metaphor, it may be that Mr. Mavor is, after all, a bigger boa constrictor than I am, and that by his exertions he will, as it were, swallow me up so that I shall be *concentric* with him. I face this position with equanimity, because I shall then be found the warmest advocate of a *system* consisting of an armoured insulating tube with one "accessible" conductor inside!

Answering the "*communicated*" *remarks* so far as they touch on points not specifically covered in my reply, I think Mr. A. T. Snell is somewhat inconsistent in his remarks. He quotes abstracts from the rules of *one* of the United States insurance companies, and argues from this that unarmoured conduit is, in his opinion, likely to cause trouble and a fire risk. In my paper I stated that American practice was not yet uniform in respect to two wires in an unarmoured tube, and admitted the desirability of using an armoured tube, on account of its extra mechanical strength. Mr. Snell's anxiety should be partly dispelled if he searches the records of the *combined* insurance interests, and finds that *not a single fire* is recorded as having occurred in connection with the wiring of the 2,000,000 lamps installed in "Interior Conduit" insulating tubing; and I can further add that the bulk of this tubing is "unarmoured," and much of it contains two wires in a tube, and wires which have far less insulation than that standard in this country. Does Mr. Snell consider that the lack of mechanical strength in the compo pipe now used so largely in England (with both wires in the tube) proves that *two* compo tubes should be used? Again, it is not fair to quote the ruling of one particular insurance office in respect to the function of the insulating lining. It is now a fact that insulated iron pipes are freely acknowledged *superior* to "plain" ones; and, had Mr. Snell looked to other sources of information, he would have found that the usual test obtaining in the United States for the efficiency of wires and conduits is made with positive and negative conductors in the conduit and the metallic portion of the conduit connected to one or other pole. This practically precludes the use of all conduits not internally insulated. Experiment will also, I think,

convince Mr. Snell that a suitable insulating lining *does* subdue any arc which (under any practical conditions) can occur in a conduit. If insulated iron pipe offered no other advantage than protection to the insulation on the wire when "drawing "in"—due to the lessened friction—this would alone, I think, gain its extended use, and place it beyond the competition of plain iron pipe. Mr. Snell quotes an instance where a "short-"circuit" on a concentric feeder burnt out the iron pipe ($\frac{1}{4}$ inch thick) surrounding it. In the records above referred to, dozens of cases will be found of plain iron pipe "burning out;" and it is this experience of the American insurance authorities—for they have gained much—compared with the fact that *not one burn-out is recorded of insulating pipe, either armoured or unarmoured*, which confirms the majority in favour of an insulating tube. Mr. Bathurst.

Mr. W. H. Tasker's difficulty in understanding why I advocate that both conductors should be together in the armoured insulated tube, and the disadvantage of this practice in respect to an ordinary metal tube, is covered by the above remarks. I was glad to receive confirmation that his experience in underground mains distribution compelled him to favour "conduit" construction for interior use; but it is unnecessary for me to remind him that in many respects the conditions to be met are quite dissimilar, or that experience approximates to "similarity" according to the time integral.

I do not think that Mr. J. Sheppard's statement as to the 25 per cent. increase in the number of fires along the main streets he selects, affords any proof that electricity is the *cause* of them, or that the use of electricity is answerable for the increase. The public now demand greater illumination, and the buildings have increased in size, so that perhaps the comparative or average risk is enlarging; but, if I leave wood-casing wiring work out of the consideration, there is, I hold, little doubt that electric lighting *is* truly acting as the friend of the insurance authorities by reducing their possibility of loss.

Gentlemen, I thank you.

Mr. Mavor, in reply, said: Mr. Geipel, who was the first of Mr. Mavor.

Mr. Mavor. the speakers, opened his remarks by criticising the high standard of insulation set by the supply companies. I think the companies are perfectly right in setting up a very high standard indeed, because of the susceptibility of double wiring in wood casing to the attacks of moisture, and the many other ways in which faults are liable to occur in it. It is only by setting a very high standard—in fact, what seems an almost impossibly high standard—of insulation, that good work of its kind—good work of this bad kind—can be secured; any withdrawal from the high standard would be taken as a license to do inferior work, and would inevitably lead careless contractors to be still more careless; even under the existing rules much inferior work is passed for lack of efficient inspection. Mr. Geipel favours wood casing because the whole of the work can be done by joiners. The whole work is too often done by joiners, and I daresay we have all seen examples of joiners' joints. He objects to concentric wiring because it requires a tradesman, a man who can use a soldering bolt, to erect it. I think that is one of its very strongest points. It compels good work. Mr. Geipel does not think the wood-casing system as at present erected is unsightly. Well, that, of course, is a matter of opinion. I think it is. Mr. Geipel says a large number of houses are wired in London where the casing is invisible. I do not know whether Mr. Geipel has discovered an invisible paint: if he has, the sooner he advertises it the better; but if the casing is not on the surface, and not visible, I doubt very much whether it exists at all, because in a completed house we know that wood casing simply cannot be laid under the floors without pulling them practically to pieces. If the wood casing is there, and is invisible, he is strangely at variance with Mr. Langdon's practice. Mr. Langdon believes in wood casing where you can have it on the surface, but only on the surface where it can be seen. Wherever it goes under floors or above ceilings he must have the conductors in wrought-iron tubes. Those double-wiring advocates curiously differ in their practice. Mr. Geipel has, I think, misunderstood my remarks with regard to burying concentric conductors in plaster. There is no reason why you

should bury the conductors if you prefer to have them on the surface, but that concentric conductors may be safely buried is surely no argument against them. The objection to burying the conductors is born of wood casing. We have many thousands of lights wired in private houses and such buildings, and we have never yet had to remove a conductor because of a fault arising from any cause whatsoever. Mr. Geipel says that cost alone is the vulnerable point of double wiring and wood casing. I say cost is not alone the vulnerable point; the whole system bristles with vulnerable points: every joint you have is a vulnerable point; every one of your crockery fuse bases and cases is a vulnerable point; every one of your double-contact lamp-holders is vulnerable; in fact, the whole thing is vulnerable, unless you make it systematically water-proof and damp-proof from end to end. That is the only effectual way to make your wiring invulnerable. Mr. Geipel's general statement alleging invulnerability is really no reply to my detailed criticism of wood-cased double wiring. With regard to the comparative cost of double wiring and concentric wiring, this is a very difficult question, because contractors' estimates for double wiring to the same specification differ so greatly. If you compare concentric wiring with double wiring, you must compare concentric wiring with a first-rate job in double wiring; because concentric wiring is essentially a first-rate job, and should not be compared with third-rate double wiring. Where you do compare it with a first-rate job in double wiring, concentric is invariably cheaper. I have never seen a building yet which I could not wire more cheaply with concentric wiring than with double wiring, and make a good job of it. The only point in Mr. Bathurst's paper that I wish to criticise is one of the illustrations, which is a libel on concentric conductors. If he examines his illustration of an alleged concentric conductor, he will find it very much eccentric; and I hope before being permanently included in the Proceedings this will be corrected. The next speaker was Mr. McLean He referred to the pretty things he saw on the table, and was of opinion he could show quite as pretty things in his double-wire Mr. Mavor.

Mr. Mavor fittings. It is rather unfortunate Mr. McLean occupied a back seat. I am quite sure if he had come down and inspected the samples more closely he would not have made so rash a statement. The same gentleman asks how many concentric joints are beneath floors and behind plastered walls. There are many thousands of them, and we have never had cause to get at any of them. Mr. Langdon was the next speaker, and he advocated inspection of wiring by the supply companies. It seems to me that it is not the business of supply companies to give the necessary inspection. Mr. Langdon thinks it a weak point in my proposal regarding inspection by insurance companies, that suitable inspectors could not be found in small towns. My reply is that you must include the small towns in districts and provide district inspectors. I do not know whether this objection to his own proposal has occurred to Mr. Langdon—that it only provides for buildings supplied from public companies, and leaves out in the cold altogether the thousands of isolated installations throughout the country. Mr. Swinton is under the impression that two staffs of wiremen are necessary. This is quite a mistake, as several contractors who have adopted concentric wiring have found out. There is really nothing in concentric wiring that any workman who can use a soldering bolt cannot pick up in half an hour. Not only are two staffs of men not necessary, but the staff of men required to do any particular job is very much reduced. To a job where with double wiring half a dozen joiners and a couple of wiremen would be sent out, with concentric wiring you would send out two joiners and two wiremen. The joiners are required to fix the wood bases for fittings, switches, &c., and for lifting flooring boards where required. The total amount of labour on the job is very largely reduced; this is the most difficult kind of labour to supervise, and therefore its reduction is a very important point indeed. Mr. Swinton. and several of the speakers to-night have spoken of the current-carrying capacity of wires in relation to the sizes of fuses. I think the current-carrying capacity of the wire should have very little to do with the fuses. There is very little danger, as Mr. Swinton and Professor Ayrton have said, of a

conductor being overheated throughout its length; the danger is from heat being concentrated at any one point, and therefore I think the fuses should not be in proportion to the size of the cable, but to the maximum current which they (the fuses) have to carry, and they should have as small a margin over that as safely may be. This is an extremely important point, and I think, since the rules of this Institution are under revision, an additional rule limiting the amount of current which may be allowed in any one conductor within a building would be an advantage. I submit that something like 50 or 60 amperes should be the limit. Increase the number of mains, and keep the main fuses as small as possible. Under present conditions many internal cables are protected by fuses which would easily carry from 10 to 15 E.H.P. If a fault occurs which is not a dead short-circuit in such cables, dangerous local heating might take place without making the fuse operate. Mr. Antill thinks the curve given with my paper does not serve its purpose sufficiently to warrant its being shown. I think it does. We all know perfectly well that the number of wiremen employed at different times of the year varies considerably, and I think that this curve does show this sufficiently approximately to warrant its being given. The curve given is the lamp curve for Glasgow, and the great majority of the lamps wired there are shops and offices; very few of them taking more than two or three weeks, and many of them only one week, to wire, so that the curve is an approximately true indication of the number of men employed at various periods of the year. With regard to earthing the distributing system, my opinion is that the feeding points are the proper points to earth. Insulate the feeders up to the feeding points, and at every feeding point have a definite earth, of such a character that it can be removed for testing purposes if necessary. The three-wire system with earthed middle and concentric branch wiring appears to me an ideal method. Mr. Jones spoke of the unsightliness of concentric wiring, and thinks it is not suited to internal house work. This, I may say, is because Mr. Jones has not seen it, and I would be very happy to show Mr. Jones examples of such work which Mr. Mavor.

Mr. Mavor. will entirely remove his impression. Mr. Swinton was under exactly the same impression until he had an opportunity of inspecting such work.

Mr. JONES: That was in Scotland, I think.

Mr. MAVOR: It was. I can now, fortunately, show houses similarly wired in England, and I would be very happy to give Mr. Jones, or anyone else, an opportunity of inspecting them. Mr. Addenbrooke referred to ship wiring. Concentric wiring is so obviously the right thing for ship wiring, that it may seem surprising that it is not universally adopted. The reason is this: Wood casing is nearly always included in the shipbuilder's contract. When the shipbuilder or owner, therefore, takes his tenders for the lighting of the ship, the contractors tender for the wiring only, without the joiner work and wood casing; so that in tendering for concentric wiring, which abolishes wood casing, concentric wiring is obviously very seriously handicapped. If the cost of concentric wiring is compared with double wiring plus wood casing, there is no doubt that concentric wiring is cheaper. With regard to Professor Ayrton's remarks, I almost wonder whether Professor Ayrton is interested in some cable company: his extravagant views with regard to the sizes of cables would almost indicate that he is. Professor Ayrton, and a great many other speakers too, seem to be bent upon drawing the wires in and out of tubes. Why on earth should you draw your wires out of the tubes? If you put a job up such as will last, why do you want to draw your wires out? I cannot understand it. We never have occasion to get out our wires; and why you should go to all the trouble of providing conduits and blowing in chalk, and the like, to facilitate the drawing in and out of your wires, is quite a mystery to me. This demand for means of drawing out the conductors is a damaging admission of the weakness of the system.

Mr. Dykes mentions an installation where he has "a sample "of pretty nearly every kind of wiring." There are many such cases where contractors, in their honest efforts to meet the conditions, succeed in introducing examples of nearly every kind of wiring. We call ourselves engineers: is there an engineer among us who ever carried out such a job who could point to

it and say that as an engineer he was proud of it? Surely not. The concentric *system* sweeps away all these ragged expedients, and replaces them by a consistently mechanical job from end to end, such as an engineer may own without blushing. Let those who for dread of the direful nail fear to bury concentric lead-covered conductors in plaster, draw switch and bracket wires into iron pipes where under plaster; and where mouldings are required to cover wires in panelled rooms, by all means use them. Why not? The continuity of the concentric system is independent of such detail. Mr. Mavor.

Mr. Rawlings asks how to fit up a French scroll bracket with C.C. wiring. This is exactly twice as easy as with double wiring. As Mr. Rawlings says, such brackets cannot be screwed into junction-box bases. There is no necessity. The bracket is wired with single wire, and this wire is jointed to the inner of the concentric conductor, and the bracket body, which is the return circuit, is jointed to the outer of the C.C. conductor.

The few critical remarks that have been made were by gentlemen who had not experience of, or even seen, concentric wiring, and the points raised by them have been fully answered by others who have had the good fortune to see and have experience of it. Mr. Wallis-Jones, who had never seen a concentrically wired private house, doubted its suitability for this purpose, and Mr. Rawlings thinks it unsuitable for wiring ornamental fittings. But Mr. Swinton, who has seen a highly decorated house, and one with many Louis brackets so wired, pronounces concentric wiring admirably suited to such purposes. While Mr. Swinton, who had only seen, but not experienced, C.C. wiring, thought a special staff of wiremen would be necessary. He, in turn, is answered by Mr. Corlett and others who have had experience, and found no difficulty whatever in carrying out the work with their usual wiring staff. Doubters in regard to freedom from short-circuit are referred to Mr. Unwin's valuable testimony.

The fact that this protracted discussion has elicited no adverse criticism (Mr. Bathurst's remarks are here ignored) of concentric wiring is significant of its very strong position, and the unanimous chorus of approval from those who have used it must have done much to dispel groundless prejudices against it.

Mr. Mavor. Mr. Human's frank, straightforward statement of his position with regard to the relation of electric light to fire risk is interesting. If I understand him aright, his proposition is to abandon inspection of wiring by insurance companies, and to meet any increase of fires by an increase of rates. The boldness of this policy is more apparent than its wisdom. Such a movement, if generally adopted, would be checkmated by the formation of a company which would reduce the risk due to bad work by efficient inspection, and whose rates would be proportionally lower.

Inspection by some one is an imperative necessity.

Much has been made in the discussion of the question of cost. After the first question, namely, Is the system a good one? is answered in the affirmative, comes the next in importance, Is it a cheap one? I reply emphatically, the concentric system is a cheap one; and, in many cases, costs less than the cheapest and nastiest of wood casing.

Mr. Binswanger's remarks regarding costs are very true and very much to the point. As he says, the cost is largely regulated by the demand. The recent large demand for wood casing and accessories has reduced the cost of these to a minimum, and in this respect any rival system is at a disadvantage. The increasing demand for C.C. wiring is rapidly reducing the discrepancy in cost, which even now exists only in a limited class of work. In C.C. wiring lies the solution of the problem of cost.

Referring to the proposal to use one highly insulated wire concentrically within a metal pipe: This has occasionally been used; but I am quite certain that any system involving the use of rigid pipes cannot compete in cost, for general use, with the lead-covered C.C. system, in which the conductor carries with it its protection. These remarks apply even to house work where it is desired to further protect by an iron pipe the switch and bracket wires laid in plaster. The adoption of the pipe system involves the sacrifice, not only of the flexibility, which is so great an advantage, but also the air-tightness of the C.C. system as at present used, upon which Mr. Crompton justly laid stress.

And now with regard to Mr. Bathurst's remarks. I presume Mr. Mavor. Mr. Bathurst has read my paper, and I must, therefore, accept some responsibility for the astonishing ignorance of concentric wiring betrayed by his remarks. I really have not enough patience to follow with corrections the several pages of Mr. Bathurst's absurdities. But I must protest against his distortion of a paragraph in my paper to make it serve his own purposes. Mr. Bathurst does wrong to attribute to me the advocacy of "a "light insulation over the whole length of the outer conductor, "except at distant ends;" and he does doubly wrong when he italicises "light insulation" to support his own argument in favour of lightly insulated twin conductors drawn into insulated tubes. My remarks were made with distinct reference to outside mains or feeders, and had no bearing on internal wiring. Mr. Bathurst may spare himself the trouble of submitting to the Admiralty his rigid conduit system. His suggestion in this connection shows how very little he understands of the conditions he proposes to meet. However, I do not wish to be too hard on my friend Mr. Bathurst, especially as since writing his reply he has had an opportunity of inspecting a first-rate example of a concentric wiring installation, and of having many of his illusions dispelled.

I have to thank the gentlemen who have spoken on the subject of my paper for their appreciative remarks, and especially those users of concentric wiring who have so generously commended it.

The following paper was then read:—

HIGH-VOLTAGE LAMPS, AND THEIR INFLUENCE ON CENTRAL STATION PRACTICE.

By G. L. ADDENBROOKE, Member.

In the spring of 1891, which was the last occasion when the Mr. Addenbrooke. Alternating *v.* Continuous Current controversy came prominently before this Institution, and when Mr. Crompton brought forward his feeder argument, I had the honour of opening the discussion,

Mr. Addenbrooke. and subsequently continued the argument in the technical Press, besides going into it privately with Mr. Crompton.

I was not, however, convinced of the superiority of *low-pressure* direct supply, and on the old premises I remain unconvinced still; but I saw that the advantages of the two systems were in many cases very nearly balanced, and if one or other was ultimately to prevail it would probably be for some other reason than lay in the arguments which had so far been brought prominently forward on either side.

It was, in my mind, useless to say that the two systems were each the best for certain situations; for how was the line to be drawn? or, in some cases, were we to have both systems in one town? Though a possible, this did not seem to me a desirable solution.

The question is not merely an academic one; hundreds of thousands of pounds are every year now spent on electric lighting, and that a large portion of this sum should be spent in a way that is not the best and most permanent is a serious matter.

Besides this, as a consulting engineer, I found my position an unpleasant one. What was I to recommend to my clients? and if I halted between two opinions, what would my clients think of me? I regret that in these matters I have not the assurance of some gentlemen who, I understand, circularise all town councils, keep their own touts, and are prepared to give cut and dried verdicts without hesitation on engineering points which, I must confess, I approach with a certain amount of awe and misgiving, and a very serious sense of responsibility.

Now it struck me four years ago, as I daresay it did others, that, as the two methods had been argued over so carefully without any definite conclusion being arrived at, probably some outside and fortuitous circumstance which neither side had taken account of would ultimately turn the balance one way or the other.

Possible Sources of Influence on Central Station Practice.

I therefore made a careful survey of the field, and the only eventualities I could think of, or which seemed likely to have a

very important bearing on the problem, were the following, viz.: the introduction of— Mr. Addenbrooke.

1. An altogether new form of lamp.
2. A cheaper material for mains than copper.
3. A high-voltage incandescent lamp.
4. A much more economical incandescent lamp of the present voltage.
5. An improved and much cheaper storage battery.

Respecting a new form of lamp: After having seen Tesla's experiments at the Royal Institution, and after having learnt privately the views of some of our leading investigators on the field which they opened, I must say, as a practical man, I did not see any immediate hope of commercial success in this direction, however interesting the results might be scientifically.

As regards the chance of a cheaper conductor being forthcoming, I have dealt with this question at length in a recent article in the *Electrical Review*.

Owing to the cheap rate at which aluminium can be produced, and will increasingly be produced in the future, and since the conductivity of aluminium is 56 per cent. that of pure copper of the same section, the chances of aluminium ultimately supplanting copper are strong, but the change will undoubtedly be a comparatively slow one. The possibility of this, however, points to a reduction in the price of conductors; and this, of course, would tell somewhat in favour of moderate pressures.

Again, as even in moderate-pressure mains insulated with bitumen or other compounds the cost of insulating is twice the cost of the conductor itself, in the sizes usually employed, it is quite conceivable that very important economies may be effected in this direction. It is obvious that improvements of this character would probably tell more in favour of moderate pressure than of high.

Having thus disposed of the conductor question, we come to the third and fourth alternatives I have mentioned as likely to influence central station practice, viz., the introduction of a lamp of higher voltage, or a more economical lamp of the present current-voltage.

Mr. Addenbrooke.

When thinking over the matter in 1891, I saw that, as fairly good lamps of 8 candle-power for 100-volt and 110-volt circuits were being made, two of them could be put in series, and that we should get very simply a 16-C.P. lamp of 200 to 220 volts. This, however, involved giving up 8-candle lamps except two in series, which, as the charge for current was then usually 8d. per unit, was a serious matter, and again, as there were two filaments in each lamp, the breaking of either of which would spoil the lamp, this also introduced an important objection, particularly as the Ediswan monopoly maintained the price of lamps at 3s. 6d. for ordinary voltages, and could hardly be expected to supply lamps which would be more expensive to make, except at an enhanced price. The prospect of obtaining high-voltage lamps did not, therefore, at that time appear bright.

Time has, however, brought about great changes in the lamp industry, due largely to the expiry of patents, which quickly led to numbers of good lamps being placed on the market at less than one-third the price formerly charged, and at the same time brought active and pushing competitors into the field.

Two years and a half ago, finding some disposition abroad to adopt higher voltages, I drafted an article pointing out the enormous gain which would accrue in the distributing system if higher voltage lamps were adopted, intending to send it to one of the journals. The question, however, then appeared somewhat problematical, and other business led to the article being put on one side. I did not, however, forget the matter, and last December year, finding that one or two firms were trying to introduce lamps of 200 volts, I looked over my draft again, and, having somewhat elaborated it, sent it to the *Electrical Review.* The article attracted the attention of Mr. Baynes, then of Bradford, and he wrote detailing his experience, and the experiments he had made with high voltage. Since then the matter has advanced by leaps and bounds. Several lamp makers are undertaking to supply 16-C.P. lamps of voltages up to 230 and even above; and not only this, but Mr. Stearn and one or two other makers are offering lamps up to this voltage of 8 C.P. also, and guaranteeing a fair economy. The lamps are also being offered at moderate prices.

Low-tension central station engineers have not been slow to perceive the facilities these lamps offer. In some cases they have been adopted publicly, and in other cases private experiments are being made on them, with satisfactory results. I also hear from those manufacturers who are catering for the market that the demand for high-voltage lamps is steadily and rapidly increasing. Mr. Addenbrooke.

The adoption of these lamps is, of course, somewhat in the tentative stage; but so much progress has been made, and the results attained so far are so good, that no one can doubt that in a year or two they will become a permanent institution.

It may also be noted here that since this paper was sent in I see that Professor Kennedy has considered the 230-volt lamp sufficiently sound to recommend the Town Council of Edinburgh to adopt it.

Concurrently with this development there has been a tendency towards the use of lamps of ordinary voltage but of higher efficiency, and I must say that until recently I have been unable to quite make up my mind which was the best of the two lines to work on—whether it would be better to use lamps of 100 voltage and taking 2½ watts per C.P., or lamps taking 4 watts per C.P. with a voltage of 200 or 220. I think, however, the matter now admits of being argued out pretty clearly.

By a reduction of current per C.P. in the proportion of 2½ to 4, mains of a given capacity would do nearly double the amount of lighting with the same expenditure of energy.

Energy in itself is very cheap, however, and any fair-sized central station could supply double the quantity of energy it is now doing at 1½d. per unit for the extra current, if this did not entail extra expense for mains.

Now, by doubling the voltage, we reduce the size of the mains to one-fourth, other things being equal; consequently the mains for a station using 220-volt lamps consuming 64 to 70 watts per 16-C.P. lamp, to give the same percentage loss, would not be much more than half the size they would be if the station supplied 110-volt lamps consuming 2½ watts per C.P., as the current would be nearly the same in both cases.

As the cost of mains is such a very large proportion of the

Mr. Addenbrooke. whole central station cost, and as energy can be generated so cheaply, I am fairly confident that, even if a good 2½-watt lamp were obtainable, it would pay better to use 220-volt lamps taking nearly double the current.

Conversations with lamp-makers, and recent publications on the subject, have convinced me that a good 2½-watt lamp of 100 volts has yet to be attained, and will probably be a very difficult thing to achieve, unless absolutely even pressures in the mains can be guaranteed. The opinion of lamp-makers appears universally to be that a 220-volt lamp at 3½ to 4 watts per C.P. is a more practicable and attainable object than a 100-volt lamp at 2½ watts. They seem also unanimous that if a good 2½-watt 100-volt lamp could be made, a good lamp of 220 volts, and of better efficiency than 4 watts, would be forthcoming.

It therefore appears that by taking a 220-volt lamp now we shall get all the advantages of high voltage, and in time shall get nearly as efficient a lamp as if a lower voltage were used, while the high-efficiency lamp is even now in a far less forward state of development than the high-voltage lamp.

Consequently, it seems clear that the high-voltage lamp is the better line of the two at present.

Besides this, we are anxious to cheapen the cost of current so that it may also be available for power purposes, and thus small economies in consumption will be of less and less moment.

It is, therefore, obvious that not only in the present, but for the future, the high-voltage lamp is likely to be the better, and that it is safe to run the risk of being unable to use very economical lamps, provided decent ones of high voltage can be obtained.

As I thought it would give a practical basis to this paper, and would be of interest to members to see specimens of some of the various high-voltage lamps which are being made, I have written to leading makers on the subject, and through their kindness am able to submit a number of 220-volt lamps, concerning which I will now give the particulars supplied by the makers.

Lamps to be arranged to burn.

Present data from makers, &c.

I shall not pursue this branch of my subject further, as it would be more suitably dealt with by a lamp manufacturer in a special paper; but I think enough has been said, coupled with the knowledge members already have of the subject, to show that high-voltage lamps are thoroughly practical for central station work, and I therefore pass on to consider how far it is desirable to use them, and what effects they are likely to have on central station practice; this being more immediately the subject of my paper. Mr. Addenbrooke.

LIFE OF HIGH-VOLTAGE LAMPS.

We can, of course, hardly expect the life of these high-voltage lamps to be as long as that of lamps of half the voltage, while at the same time they will be rather more expensive, consequently there will be a greater expenditure for lamp renewals when they are used; and it is advisable, I think, to try and arrive at a figure for this before proceeding further.

If the life of an ordinary 16-C.P. lamp of 100 volts is 1,200 hours, and it consumes 64 watts, during its life it will consume 77 B.T. units, which, at 6d. per unit, amounts to 38s. 6d. If the cost of the lamp is 1s. 3d., its cost per unit of current consumed is 0·2d., or $\frac{1}{5}$d., or about 3 per cent. of the cost of the current.

For an 8-candle lamp of 100 volts, lasting 800 hours and taking 36 watts, the consumption of current is 29 units; and at the same price for lamps, the lamp cost per unit of current consumed is about 0·5d., or $\frac{1}{2}$d., or about 8 per cent. of the cost of the current.

I have assumed the above life for these lamps because I think, after burning the number of hours indicated above, most lamps would be best thrown away; though I am perfectly aware lamps often last twice as long as I have assumed, and they can also be purchased for 20 per cent less from reliable makers.

200- or 220-volt lamps will, of course, cost rather more, and their life would be rather less, but I believe I am putting the case more adversely for the higher voltage lamps than is

Mr. Addenbrooke. really true, in taking the cost as double the above rates for lamp renewals where high-voltage lamps are used.

The cost of lamp renewals would then be 6 per cent. of a customer's bill if the current was 6d. per unit for 16-C.P. lamps, and 16 per cent. if 8-C.P. lamps were used.

Supposing the number of 16-C.P. lamps installed to 8-candle lamps is about as 1 : 2—which is, I think, about a fair average—an all-round reduction of 6 per cent. in the charge per unit of current would cover the *additional* cost of lamps, if lamps of high voltage were used; at 6d. per unit for current this is about one-third of a penny per B.T. unit.

Such figures as these can only be approximate, but I think you will agree that they would not be far out in practice, and may be improved upon, and also that they make it clearly manifest that the extra cost of using high-voltage lamps offers no appreciable bar to their introduction, providing that their other countervailing advantages are in excess, with which branch of the subject I will now deal.

Effect of using High-Voltage Lamps on Distribution.

On this point I do not think I can do better, as a commencement, than quote from my article in the *Electrical Review* of the 11th of January, 1895:—

" How great a gain there is in distributing current at a higher " voltage, and how much it simplifies the distributing problem, is " not at first sight fully apparent, though everyone recognises that " there are advantages. The advantages may really be said to " progress as the cube of the voltage, up to, say, about 200 volts. " For let us suppose we have a station on all of whose circuits the " lamps require 200 volts to incandesce them, instead of the usual " 100 volts. In the first place, having doubled the pressure, we " may extend our mains double the distance at the same current- " density, with the same percentage loss; but at the higher " voltage the same current-density in a given sized main will give " us twice the energy and light twice the number of lamps. " Consequently, without increasing the sectional area of the mains, " we can do four times the lighting with the same mains, or the

"same amount of lighting at four times the distance, with the "same percentage loss. Then there is a further gain, for, since "we can extend the mains four times as far from the central "station with the same percentage loss, the area which can be "served from a single station is 16 times greater at the higher "pressure than at the lower. Mr. Addenbrooke.

"Presuming, however, that this argument is not pushed to its "extreme limits, it is well within the mark to say that at 200 volts "nine or ten times the area could be better served on the three-"wire system from a single station than is now the case at 100 "volts; not only is this the case with the feeders, but it extends in an "even greater degree to the distributing system. At present there "is no doubt that there is an inconvenient fall of voltage in the "distributing mains, and the internal wiring of houses, which "leads to irregular and unsatisfactory lighting, and which is "under existing circumstances, whatever system is employed, ex-"ceedingly difficult to remedy. If by any means the voltage "could be increased to 200 volts this would practically vanish, "distributing mains might be carried three times their present "distance from the feeding point, and the fall of potential in "houses would be merely nominal on the present basis of wiring, "instead of frequently amounting to 1–2 volts or more. By these "means the number of feeding points in a given area would of "course be much reduced. The same fittings and wiring as are "now used would be applicable, and the voltage does not go "beyond the Board of Trade limits."

This was a general statement, made largely with a view to point out to manufacturers what a field it would open if they could produce a commercially satisfactory high-voltage lamp.

During the last 18 months manufacturers have seen the advantage of exploiting this field, with results which have already been detailed above. Consequently it is desirable to look a little more closely at the distribution problem under its new aspect, and I will, therefore, ask your particular attention to the figures which I now propose to lay before you.

It is generally acknowledged that in the three-wire system at 110 volts it is not economical or very practical to distribute

Mr. Addenbrooke. current at a radius of much more than three-quarters of a mile from the central station, except under special circumstances. The area which can therefore be economically served from such a station is about one and a half miles each way, or about two and a quarter square miles.

In his well-known feeder paper Mr. Crompton gave figures which he argued showed that a feeder on the three-wire system supplying 110-volt lamps could be laid and maintained, and would involve the same loss of energy, taken over the same day, as would an alternating feeder, including transformers, instruments, and switching gear, the length of the feeders in each case being 2,400 yards.

These figures were strongly attacked by the alternating party, myself amongst the number; the most legitimate point of attack being that Mr. Crompton had assumed a loss of 30 per cent. at full load on the low-pressure feeder, which was considered excessive on account of the extra plant it would entail at the central station.

Had Mr. Crompton put the length of his feeder at about 1,400 yards, or a little over three-quarters of a mile, and had he used a density of about 500 amperes per square inch—which is about the practical density—the loss would have been 16 per cent. for the continuous-current feeder at full load, and few alternating men would have seriously combatted that on the whole the continuous-current feeder was as economical and desirable as an alternating feeder. The figures would then agree with the generally current comparison which I have mentioned above, and which I propose to use as a basis of argument in order to avoid disputes.

Now, from data I have collected, it appears that in such places as the centre of large towns there are perhaps 30,000 inhabitants per square mile, though ordinarily the population for a square mile of a town does not appear to exceed 16,000.

A low-pressure station on the three-wire system with 110-volt lamps can therefore serve economically about 60,000 to 70,000 people in the centre of large towns, and about 35,000 in districts the centres and in provincial towns. If, therefore, we

Mr. Addenbrooke.

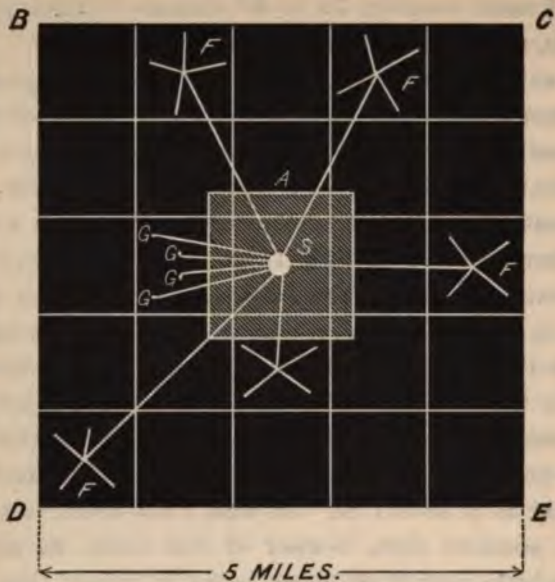
wished to light London, with its 4,000,000 population, on this basis, taking the average population at 25,000 per square mile, we should need, roughly, 70 to 80 stations to light the whole metropolis, not counting the extreme suburbs.

If, however, in the direct supply system the voltage is double, the position is altogether altered, and a comparison between the transformer and direct supply systems under these circumstances will lead to very different results from those so far given.

Theoretically, if 220-volt lamps are used, we can extend the feeders four times as far as if 110-volt lamps are employed, and therefore the area which could be lighted from each station is 16 times as large. I do not intend to take full advantage of this facility in the calculations which I propose to lay before you, as I consider that the fall of voltage is too large in low-pressure central stations at present, and that the voltage of the lamps at different points of the distributing system is not kept as near the normal as it should be. In what I am about to say I shall therefore consider that, instead of four times, we extend our feeders a little over three times as far as before, thus securing better regulation and a smaller percentage drop in both the feeders and distributing system, together with the great saving in copper. If, then, we can extend the lighting radius three-quarters of a mile from a low-pressure direct supply station with 110-volt lamps, we can extend it, on the above basis, 2½ miles at 220 volts, which means that we can cover an area of 5 × 5, or nearly 25 square miles from one station—that is, 11 times the area we could before. Instead, therefore, of serving 60,000 people in the central districts, one central station would serve 700,000, and over a quarter of a million in the less central districts. Taking, then, the population of London as 4,000,000 without extreme suburbs, about six or seven stations would comfortably cover the whole area. Now this is a number which is directly comparable with the number of stations at present being operated by the gas companies; and to my mind it is doubtful if it would be desirable to reduce the number of stations below this figure for so large an area, even if it could be managed.

It would be interesting to go into this metropolitan lighting

Mr. Addenbrooke. problem further did time permit, but it does not, and I must ask you now to turn your attention to the provinces.



S—Central station.

A—Area economically covered by low-pressure mains at 110 volts, three-wire system; feeders ¾ mile long.

B, C, D, E—Area economically covered by a distribution system as A, but with lamps at 220 volts.

F, F, F, F—Feeders with short sub-feeders, each feeder supplying a square mile of distribution.

G, G, G, G—Short direct feeders, distributing four to the square mile.

Take maps of Birmingham, Liverpool, Glasgow, and Manchester, and cut out a piece of tracing paper to represent 25 square miles on the same scale as the map. Lay the tracing paper over these maps, and you will find that two stations, or at most three, will cover not only the whole of these great cities, but the suburbs for a couple of miles outside.

For the general run of large towns one station would amply suffice; and for the smaller ones one station would, of course, permit of lighting over the whole area at a very small expense for mains.

Before a technical audience like this, however, it will doubtless

be more satisfactory to investigate a particular instance than to proceed further with general statements. Mr. Addenbrooke.

At 220 volts pressure an ampere represents 220 watts; therefore one-third ampere represents 73·3 watts. Now at 4 watts per C.P. a 16-C.P. lamp takes $16 \times 4 = 64$ watts, and an 8-C.P. lamp 32 watts.

We shall therefore be sufficiently near for the purposes of this calculation, and shall be allowing a sufficient margin, if we assume that a 16-candle lamp takes one-third ampere, and an 8-candle lamp one-sixth ampere at 220 volts.

Next consider the distributive system. There are two points needing attention: the first is, How far, and over what area, can we spread our network from the feeder points? the second is, What drop should we allow on the feeders themselves?

But before going into these matters further we must settle what shall be our greatest drop from the feeder point to our furthest lamp on the network spreading from it. The variations which are permitted at present are too great, and would have to be reduced in time anyhow. I therefore do not intend to adopt the present practice as a basis, but to take as the limit an extreme fall of 2 per cent. on the distributing system from the feeder point to the furthest lamp at the tops of the houses; that is, lamps near the feeder would be 1 per cent. above their proper voltage at full load, and extreme lamps 1 per cent. below.

This is, I think, as large a variation as good practice would allow, though it is less than half what is considered permissible now. Having settled this, the following data and table will enable us to see at a glance the best method of designing the mains, and their cost.

1. A bar of copper 1 inch in section and 1 mile long weighs approximately 9 tons, and its resistance is 1-22nd ohm, or 0·045.

2. Therefore a double conductor 1 mile long and 1 inch in section weighs 18 tons, and its resistance is 1-11th ohm, or 0·090.

3. I do not think it will be necessary on the high-voltage system to have the third wire in a three-wire system more than one-fifth the section of the other two, except, perhaps, in the distributing system. In fact, I understand Mr. Crompton

Mr. Addenbrooke. considers the third wire could be done away with altogether as soon as the feeder gets a good load joined up to it, so that only the distributing system would need the third wire, these wires being joined together at the distributing point.

Consequently, the weight of a set of mains on the three-wire system—the two outers 1 inch section, and the inner one-fifth of an inch—would be 20 tons per mile; and the cost for copper at 6½d. per lb. would be £1,210 for the copper in the mile of mains.

Now at one thousand amperes per square inch a main this size would carry current for 6,000 16-C.P. lamps, if perfectly balanced on the above basis, and the fall of pressure would be 90 volts in the mile, or 17 per cent. Such a fall of potential as 17 per cent. in the mile is excessive, and therefore we must arrange to work at a smaller current-density.

To enable the best current-density to be judged I have arranged the following table :—

DATA RELATING TO FEEDERS ON THREE-WIRE SYSTEM SUPPLYING 220-VOLT LAMPS – ⅓ AMPERE PER 16-C.P. AND ⅙ AMPERE PER 8-C.P. LAMP.

Current-Density in Amperes per sq. inch.	Loss in Volts per Mile of Double Conductor.	Percentage Fall of Potential at Full Load.	Kilowatts available per sq. inch Section of Outers = 2·2 sq. ins. Copper.	Number of Lamps carried by Mains 1 sq. inch Section = 2·2 sq. inches Copper.		Cost per Mile of Copper at 6½d. per Lb.			
						Per Lamp alight at once.		Per Lamp installed = Twice Lamps alight.	
				16-C.P.	8-C.P.	16-C.P.	8-C.P.	16-C.P.	8-C.P.
		Per cent.				s. d.	s d.	s. d.	s. d.
1,000	90	17	440	6 000	12,000	4 0	2 0	2 0	1 0
500	45	9·3	220	3,000	6,000	8 0	4 0	4 0	2 0
400	36	7·6	176	2,400	4,800	10 0	5 0	5 0	2 6
300	27	5 8	132	1,800	3 600	13 5	6 8	6 8	3 4
250	22·5	4 86	110	1,500	3,000	16 0	8 0	8 0	4 0
200	18	3·85	88	1,200	2,400	20 0	10 0	10 0	5 0

This table enables us to see the reduction in fall of potential which we get by reducing the current for a given section, and also the cost for copper which will be incurred for such density per mile run.

Now it is not unusual in some low-pressure central stations

to have falls of even more than 16 per cent. at full load on the longest feeder; but this is an undesirably great fall, save on exceptional occasions, such as Christmas week, or during a fog in winter, and I think, with the immense reduction in copper cost which the use of high-voltage lamps gives, it is desirable to work with smaller falls. Mr. Addenbrooke.

Suppose we accept 250 amperes per square inch as a basis, it will be seen that mains on the three-wire system will cost us 16s. per 16-C.P. lamp alight at once, and 8s. per 8-C.P. lamp per mile, and the drop of potential will nearly be 5 per cent. Now, if we assume that current is supplied 2½ miles from the station as an extreme, as we did before, our longest feeders will be about this length, the drop at full load on the feeder will be about 12 per cent, and the cost of copper 40s. per 16-C.P. lamp, and 20s. per 8-C P. lamp alight at once for the longest feeder.

If we take the network as proceeding from the feeder points at the same current-density—namely, 250 amperes per square inch —and if we agree that it shall extend rather over a quarter of a mile from the feeder point, to allow for irregularities, so that each feeder will feed a network covering half a mile square, it will be noted that the drop, including extra lengths of main for going round angles and into the houses, will be about 1½ per cent., and the extreme cost of copper per lamp alight at one time in the network will hardly be more than 4s. per 16-C.P. lamp, and 2s. for an 8-C.P. lamp, while the mean cost will be about three-fourths of this, and the mean drop of potential only 1 per cent.,—and even this can readily be reduced by a little judicious adjustment.

We therefore see that for feeders extending about 2¼ miles, and a network extending a quarter of a mile further from the feeding point—that is, 2½ miles altogether—the extreme cost for copper per 16-C.P. lamp lighted at once will be about 44s., and for an 8-C.P. lamp under 22s.

This represents extreme lengths. The average length of feeders to cover the above area would hardly be more than 1¾ miles, or ¾ of the above maxima; and the cost of the copper, on the average, in the distributing system will be reduced in like proportion. We shall, therefore, be correct in taking three-fourths of the

Mr. Addenbrooke. above sums as the average cost of copper per lamp lighted at once from station to lamp, including both feeder and network, in a station covering a town area of equal density 25 square miles in area. This is, approximately: Per 16-C.P. lamp, 33s.; per 8-C P. lamp, 16s. 6d.

Further, from practice and the tables in *Lightning*, we know that there are usually at least twice as many lamps installed as are required alight at once; therefore we may put the capital cost of mains for copper only at about: Per lamp installed: cost of copper—16-C.P., 16s. 6d.; 8-C.P., 8s. 3d.

Now it is fair to take 6 per cent. per annum as the sum to allow for interest and depreciation on the copper in the mains—say 3½ per cent. for interest, and 2½ per cent for depreciation. At this rate, on the above capital cost, the annual cost for interest and upkeep comes out at under 1s. per 16-C.P. lamp, and 6d. per 8-C.P. lamp installed.

Further, on looking through the tables of consumption of current, it will be found that 18 units per 8-candle lamp installed is a fair all-round average—at least, it is the average from *Lightning* for London and most of the provincial stations. At this rate, therefore, it will be seen that the upkeep and interest on capital for the copper in the distributing system comes to 0·33d., or one-third of a penny per unit of current sold; or, supposing the sum actually received for current is 6d. per unit, the cost for interest and upkeep on the copper in the distributing system represents less than 6 per cent. of the cost of current. Out of this cost, it will be noticed that about three-fourths of the copper is in the feeders, and one-fourth in the distributing system.

I may say that Mr. Crompton objects to the method of taking the consumption per 8-C.P. lamp installed as a basis of comparison, and I quite agree that it is rough and unscientific; and it might be well if our friend the editor of *Lightning* would look into it, and see if he could not get a sounder basis for comparison.

Mr. Crompton suggests the relation between the annual output in B.T. units, and the output which would be registered if the maximum load were continued day and night throughout the year. In this case he tells me the actual output would vary from

the equivalent of full load for 700 hours in some country towns to 1,000 in parts of London, 1,300 in Kensington, and a much higher figure for the Pall Mall and St. James's Company. 1,300 hours corresponds to a load-factor of 15 per cent.; though it will readily be seen that it is a figure of more comprehensive nature, and not exactly similar. Mr Addenbrooke.

I leave this question here, however, as, though very interesting, to discuss it further now would be out of place in this paper.

In order to complete the comparison made above, the cost of insulating and of laying the cables should, of course, be taken into consideration.

In order to set this point at rest, Mr. T. O. Callender has kindly prepared for me data deduced from their experience in supplying and laying cables, which, as the result of a large amount of practice, are beyond cavil, and which show the average cost of cables laid as compared with the cost of the copper in them. These particulars are given in the following table:—

TABLE SHOWING THE TOTAL COST OF INSULATED CABLES LAID COMPLETE, AS COMPARED WITH THE COST OF THE COPPER CONTAINED.

Character of Cables (Separate).	Armoured, laid Direct.	Plain, laid in Solid Bitumen.	Armoured, laid Direct.	Plain, laid in Solid Bitumen.
	Sq. inch.	Sq. inch.	Sq. inch	Sq. inch.
Area of cable { Outer ...	0·50	0·50	1·00	1·00
Middle ...	0·25	0·25	0·50	0·50
Outer ...	0·50	0·50	1·00	1·00
Cost of cable laid complete, exclusive of excavation ...	19s. per yd. £1,650 per mile.	25s. per yd. £2,200 per mile.	33s. per yd. £2,900 per mile.	42s. per yd. £3,700 per mile.
Excavation, cheap streets and lanes	s. d. 1 3	s. d. 1 3	s. d. 1 3	s. d. 1 3
Excavation per yard, average run of trench in towns under macadam or pavement	2 0	2 0	2 0	2 0
Ratio of cost of copper (at 7d. per lb.) to cost of complete cable laid, as 1	2·5	3·1	2·2	2·3

Mr. Addenbrooke. Under asphalte or wood the cost of excavation will run up to as much as 15s. per yard run, but this item will practically be the same whatever system is used. Moreover, as only a few of the main streets in large towns are so paved, this item is not one which need concern us particularly in a general comparison, but must be dealt with in accordance with local circumstances in each case.

It will be noticed that in the above table the middle wire is half the section of the outers; in practice it would not be necessary to have this more than one-fifth for the feeders, and in some cases it might be omitted entirely. The actual cost of feeders should therefore come out about 10 per cent. under the prices given, though I have thought better to leave the table as it was, preserving Mr. Callender's own figures.

At these rates, for a two-mile feeder of armoured cable, working at a current-density of 250 amperes per square inch, the cost, laid complete, would be about £55 per kilowatt for the maximum output; the fall of pressure being about 10 per cent. I think, therefore, that the whole distributing system—consisting of feeders, branches, local services, service boxes, and every other item, also providing for a fair proportion of the cables being laid under asphalte or wood, from such a station as I have described above, with a service extending 2½ miles in all directions—could be laid complete for £60 per kilowatt.

This is a very moderate figure as compared with the sums now spent. If we assume that 8 per cent. is required to meet interest, upkeep, and depreciation on this outlay, and if we take the output of the station at 800 kilowatt-hours maximum load on the basis suggested by Mr. Crompton, it is evident that interest and upkeep on the distributing system would cost about 1½d per unit of current sold for the whole distributing system; so that a charge of 1½d. per unit would cover all costs outside the station itself. From what we know of the cost of generating electric energy, it will, I think, thus be clear that, even in places where coal was expensive, a very good profit would be made by selling current at 4d. per unit for lighting, and 2½d. for power purposes. In making this calculation I have assumed the same density of population over

the whole area; but it is evident that this would very seldom be the case, as in nearly all towns at two miles from the centre the density of population is greatly reduced, which would mean a smaller proportion of long feeders, and consequently a less average cost per kilowatt output than I have taken. Mr. Addenbrooke.

I do not wish it to be assumed from what I have said above that the capital cost of a direct supply station at 220 volts, with feeders and distributing system extending $2\frac{1}{2}$ miles, as described above, would be as low as that for an alternating station at 2,000 volts, with transformers and 220-volt lamps, to cover the same area. It would not. Comparing feeders, I think, with the present prices of mains, and using the same class of insulation in each case (as is frequently done now)—that is, not using expensive rubber cables for the high tension—the two systems are equal in cost for feeders $1\frac{1}{2}$ miles long. As the distributing system will extend $\frac{1}{4}$ mile further beyond the end of each feeder, a direct supply station on exactly the same lines is as cheap in capital cost for an area having a base of at least $3\frac{1}{2}$ miles and covering 10 square miles. Further, as something must be allowed to the direct supply system on account of lower depreciation, and greater safety and freedom from restrictions, and ability to supply motors more easily, another quarter of a mile may easily be allowed on the feeders of the direct supply station on this account; so that the systems compare together when the base of the area served is 4 miles and the area itself 16 square miles, even if no accumulators are used.

Although this is not as large as the area I have taken as a basis, what it means can be estimated from what has been said above as to the actual areas covered by large towns. I am, of course, assuming that 220-volt lamps are used on the transformer station as well as the direct. If we assume that the transformer station employs 100-volt lamps, of course the comparison would be much more decidedly in favour of the direct supply at 220 volts.

There is no need, however, to go very minutely into these figures, because, though thoroughly practical, they do not represent what it is clear will be central station practice in the future, as I do not think it probable that any direct supply station in the future will be operated without accumulators.

Mr. Addenbrooke.

The Use of Accumulators.

This brings me to the fifth and last point mentioned at the beginning of my paper when enumerating the possibilities likely to affect central station practice in the future, viz., *the use of accumulators.*

In the earlier part of 1891 I did not see much likelihood of improvements in accumulators making any really fundamental alteration in central station practice. But I must confess that in this respect events have moved faster than I anticipated, although I have been brought sufficiently into contact with them to learn what was going on in the field, and how batteries were doing as regards upkeep.

Up till comparatively recently, there is no doubt accumulators have been rather a luxury and convenience in central stations than a commercial or economical necessity; but during the last two or three years considerable changes have been taking place. The maximum safe discharge rate for accumulators has been going up, while the initial cost has been going down, as well as the cost of upkeep; and extended experience holds out the hope of much longer life for the newer and improved forms of positive plates than has hitherto been the rule. Owing also to the method of supplying accumulators at a maintenance rate adopted by the leading firms, an engineer need have less hesitation in recommending clients to incur a large expenditure on them, and the risk is much less than formerly. Patents are also expiring, and considerable competition is arising in this trade, which was formerly such a close one.

I have lately had to make careful inquiries about accumulators in connection with work on which I am engaged, not only as regards prices, but also as to their working, and, having got particulars about the batteries in several central stations, and held conversations with the engineers concerning them, have been considerably surprised at the progress which has been made. Taking quotations from leading makers for a battery suitable for a central station, I find that the capital cost of a battery to discharge at 1 kilowatt for three hours is as nearly as possible £13 for the battery alone. Several makers assure me that such

a battery can be discharged at this, and even higher rates, every day regularly, without detriment or endangering the life of the positive plates. The above price does not include buildings to contain the accumulators, connections, instruments, or stands to hold them, which bring up the cost to about £19 per kilowatt on this basis for central station batteries. The makers tell me further that they are willing to enter into contracts to maintain such batteries in a state equal to new for about 6 per cent. per annum on their capital cost, and some makers will even go lower than this. Mr. Addenbrooke.

It will be found that these costs and rates of renewal are a great improvement on those ruling until comparatively recently.

Now I should not quote these figures unless I had, by private inquiries and in other ways, fairly convinced myself of their substantial accuracy.

Granting that they are so, it appears to me that they raise questions of very serious import in central station practice, particularly when coupled with the use of higher voltage lamps.

If an accumulator will give a discharge for three hours—that is, sufficient to cover the period of heavy load, or the time during which the large portion of the plant has to be kept running—a kilowatt capacity of accumulators will be equivalent to a kilowatt capacity in engines and dynamos.

In continuous-current stations, when an increase of output is required—which is from time to time the position of most stations—we are therefore brought face to face with this problem.

Extra plant for 200 kilowatts output, say, is required. Which is the best way of providing for it—by adding engines and boilers, or by adding accumulators and charging them during off hours from the existing plant?

Now, as I have said above, an accumulator for an extra kilowatt output will cost about £19 complete and erected, including buildings; and I think engineers will generally agree with me that engines, boilers, dynamos, and steam pipes for a kilowatt output, including buildings and all other accessories, would cost about the same sum; if foundations, flues, chimney stalk, and everything

Mr. Addenbrooke. else were considered, the comparison would be slightly in favour of accumulators. However, for our present purpose, let us assume that they are equal. We have therefore arrived at the position that the capital cost will be equal, whether we provide extra plant or extra accumulators for the increased output required, charging the accumulators from the existing plant.

As regards upkeep, if we can keep the accumulators in an efficient state for 6 per cent. on their cost, this is not greatly in excess of what would have to be allowed on plant if boilers are included; and, at any rate, the difference is not a matter of very great moment.

There is no need to say anything here on the extremely low cost at which energy can be produced if a continuous load is provided night and day.

Considering the advantages accumulators give in a central station in providing for emergencies, reducing staff, and keeping the pressure even, it is, I think, doubtful if an engineer placed in the position indicated above—as many engineers will be placed shortly—would not be wise in recommending his corporation or his board to instal accumulators for 200 kilowatts output for three hours, instead of the extra plant, when the plant was a continuous one.

How far this should proceed is a moot point, dependent upon circumstances, which would need decision in each case. Possibly somewhere about one-third the maximum full-load capacity would be about right now, but with a load-factor of 10 to 15—which is about that general in central stations—if the price of accumulators came down per kilowatt output—which I think it is likely to do in the future—or their efficiency increased, it might be found desirable to instal accumulators for as much as two-thirds, or even three-fourths, of the full load, which would place electric distribution nearly on a par with gas distribution in respect to storage.

To go as far as that is, however, not a question of the present—at any rate, in most cases—and therefore for our purpose this evening I propose to consider the accumulators as desirable for about one-third to one-half the full output.

It may be useful here to give a few general data relating to accumulators as they stand at present. Mr. Addenbrooke.

The leading makers' prices of central station batteries work out at about £13 per kilowatt on a discharge for three hours, for the plates, cells, and acid only; whilst, including stands, erection, connections, and switching arrangements, the price works out about £17 per kilowatt, or, if buildings also are included, about £19 per kilowatt.

In such a battery, I find the plates and lead cells alone would weigh about 8 cwts. per kilowatt output on the three hours' discharge basis; and that 1 cwt. of plates and cells costs a little under £2,—or the cost comes to about £40 per ton. Now, as lead costs under £12 per ton at present, and seeing how much almost pure lead, in a very simple form, there is in accumulators, it does not seem unreasonable to anticipate that in the future, when accumulators are made on a much larger scale, we may see the price gradually come down to, say, £25 per ton, with, perhaps, improved capacity and life. At least, it appears to me that there is as good hope in this direction as there is of reduction in price and improvement in quality in any other department of electric engineering. If such a consummation were attained, it is pretty clear that it might pay to use accumulators for power stations, as well as lighting, wherever an eight or nine hours day was in vogue, and that they may ultimately come to exercise a much wider influence on the future of the electric industry than most engineers have anticipated.

In order to gauge in some measure what has been the improvement in accumulators during the last few years, and since the question of the system of central station supply was last prominently before this Institution, I lately took an opportunity of talking the matter over with Mr. Epstein, and I asked him if by looking up old contracts and catalogues he could give me anything definite on the subject; in reply, he has sent me the following letter:—

"I have looked into the question of the prices of accumulators, "and I find that, comparing the prices in 1890 with the present "ones, there is, on an average, a reduction of 25 per cent.

Mr. Addenbrooke "But another and more important point is this—that whereas "the types then manufactured were only allowed to be discharged "in about 10 hours, necessitating in the case of shorter "discharges much larger batteries than required for the purpose, "the discharge rate has since then increased very considerably.

"Taking one with the other, I think I am justified in saying "that the reduction altogether amounts to quite 50 per cent."

In view of these facts, and considering that it is now the custom to buy accumulators on a moderate maintenauce agreement, and also all the added experience of the last five years' work, it will be at once evident on how much sounder a basis commercially accumulators now rest, and how much stronger the arguments in favour of their employment in central stations are than they formerly were

Upon the three hours' discharge basis, I find a kilowatt capacity of accumulators occupies approximately 4 cubic feet space, for the cells and connections, so that we get a kilowatt-hour into 1·33 cubic feet. Now a discharge of a kilowatt-hour, allowing for losses, will keep about 15 16-C.P. lamps going for one hour. Allowing that a gas burner using 6 feet of gas per hour is equal to a 16-C.P. lamp, the amount of space needed in a gasometer to store gas for the same amount of light is $6 \times 15 = 90$ cubic feet, or 70 times as much space. Of course this is not quite a fair comparison, because nothing is allowed for stands, access, &c.; but I think it will be quite fair if we allow ten times as much space for access, &c., as the accumulators take themselves. Even under these, the actual conditions, accumulators only occupy one-seventh the space which the equivalent gasometer would. We arrive, therefore, at the curious conclusion that, if the London gasometers were emptied of their gas and fitted up as accumulator rooms, sufficient accumulators for lighting London could easily be arranged under working conditions in one-seventh of the space which would be available. We have, therefore, nothing very enormous to fear in the way of accumulator houses, even if accumulators are used in the future on the most extensive scale for lighting or power purposes.

Mr. Addenbrooke.

Interesting as these speculations are, it is desirable, however, to return to what is more specifically our subject.

It is usual at present to place the accumulators in the central station, except in a few instances, such as in Mr. King's system at Chelsea, Mr. Parker's Oxford system, and a few special places. Usually under these circumstances the accumulator is subject to the heavy drop at full load, which decreases its efficiency by 10 to 15 per cent.

With 220-volt lamps the drop on the feeders within a mile radius would be much less than is usual now, and therefore the value of the accumulators would be correspondingly increased.

For longer distances from the central station than a mile, however, undoubtedly the right place in most cases for accumulators will be at the feeder points. This is the more feasible with 220-volt lamps than under present practice, because the distributing network is so much larger from each feeder, and each feeder becomes the centre of a serious amount of lighting, which will pay for individual attention.

Although from the table I have given the cost of copper per lamp installed for feeders is very moderate, yet on a two-mile feeder it amounts to a considerable sum in the aggregate; and if, by installing accumulators at the end of the feeder for one-third to half the full output, the section of the feeder can be cut down by one-third or a half, a very important saving is effected; and of course, if accumulators for two-thirds or three-fourths full load were installed, the cost of feeders would be correspondingly reduced.

This has already been recognised in practice, and many devices have been brought out for charging accumulators in series, or by the help of motor transformers using a high-tension current; but I would point out that the use of 220-volt lamps on a three-wire system does away with the necessity for any of these complications. All that is needed is a continuous-current motor transformer of the "booster" type.

In this, one armature circuit is across the mains, and wound with a high resistance and many turns, while the current to the accumulators passes through the second circuit direct; the second circuit being wound with a few turns, so that the voltage of the

Mr. Addenbrooke. main current in passing through the armature is raised, say, 30 per cent. The motor transformer then need only be about one-third the capacity for the charging current, and the cells can be charged at any time, while the circuit is supplying lamps, so that continuity of supply without complication is ensured.

By these means the cost of long feeders would be much reduced on the figures given above; which means also that it would be practicable to extend the lighting radius much further than was contemplated above at the same cost, should it be needed.

An important factor is also brought in—that, having once laid a feeder of fair size, accumulators can be added at the outer end as the lighting grows, and thus a very large increase of lighting could be gradually met without relaying the feeder or disturbing the streets, which is always an expensive and troublesome operation.

In what I have said above I have indicated a feeder to each half square mile as an average, or four to the square mile; but it is clear that, if accumulators were employed, and it were desirable to concentrate them in order to save labour and attendance, it would be very simple to run short sub-feeders from a centre, so that one distributing point where accumulators were situated, and one feeder from the central station, could be economically made to serve a square mile or more.

It is further worth noting that at 220 volts the cutting in or out of a cell makes less than 1 per cent. difference in the voltage, and not 2 per cent. as at present. This is an important consideration in keeping the light steady—a point the importance of which is becoming more and more recognised.

The convenience of the system for arc lighting does not need pointing out, as nine arc lamps can be run in series.

One more point is the effect which a general electric supply at 220 volts on the lines indicated above would have on the power supply question.

There is no difficulty in procuring already motors of any size, from 50 watts upwards, to run on 220-volt circuits, the number of amperes they take being, of course, half what is usual now; while for larger sizes, say above 3 or 4 kilowatts, they could, of course, be coupled across the two outers at 440 volts.

If we then add the facts that the drop on the feeders would be less than at present, that the current-density in the distributing system on the basis I have laid down would only be about half what it is at present,—and when we consider that there would only be 1½ per cent. fall of pressure at full load on the distributing mains, and that by cross-coupling even this would be reduced,—then it seems to me that it goes almost without saying that motors could be used to a far greater extent than at present is possible without appreciably affecting the regularity of the lighting. Accumulators at the feeding points would also be an important aid in this respect; if they were so used, the fall of voltage from them to the motors would rarely exceed 2 per cent., and under such circumstances motors of considerable size could be started and stopped (even without special starting resistances) without the rush of current being perceptible on neighbouring lamps. In this respect, therefore, the use of 220 volts is likely to be very advantageous, and do away with the necessity of having to lay special power mains—for some years, at any rate. Mr. Addenbrooke.

The utility of having generators in the lighting stations giving the current and voltage which is needed for tramway work is also obvious; in fact, it looks as if one station in future would do all the power supply for a town, the lighting being only one adjunct of its business, and that, possibly, not the largest. With most of the lighting done by means of accumulators charged during the night, and the station supplying power to the tramways, &c., during the day, it ought to be possible to secure a very fairly even all-day load with one set of plant, instead of two as at present. This would, of course, lead to important economies in generating expenses. In fact, it looks as if we could already see far enough ahead practically to enable Mr. Preece's prophecy to be fulfilled in a moderate time—"that the electric "light would ultimately be the light of the poor man as well as "of the rich."

And now I must conclude. The title of my paper was "High-"Voltage Lamps, and their Influence on Central Station Practice."

In the first place, I have endeavoured to show that high-voltage lamps are thoroughly practical. Next, that high-voltage lamps are more desirable than lamps of the usual voltage and of high

Mr. Addenbrooke. economy. I have also shown reasons why it is probable that the economy of high-voltage lamps may in time nearly approach that obtainable in ordinary voltage lamps.

Having thus tried to establish the soundness of the position of the high-voltage lamp itself, I went on to consider what influence the adoption of a high-voltage lamp would have on central station practice.

I have shown how it simplifies and renders less costly the distribution of current, and how it improves the conditions of lighting. I think I have further made it fairly clear that for nearly all practical requirements of town lighting the direct supply system will prove simpler and less costly, as well as more advantageous, than any system, whether direct or alternating, in which transformers are used; in fact, the necessity for this class of apparatus, except for special cases, seems to vanish.

I think, therefore, that, when the facts are fairly faced, there does not seem much doubt that those engineers who have advised their clients to erect continuous-current direct supply stations in the past have done wisely, and will be found to have served their clients' best interests; and that for the future, alternating-current stations, even for country towns and scattered districts, should only be erected after the most careful weighing of possibilities.

It is considerations of this character which have led me to keep very much in the background as regards central station lighting for the last four years. Having been associated from the early days with alternating currents, my predilections were in that direction; and although the position seemed secure, yet, seeing the possibility of great improvements in several directions which would tell strongly in the favour of direct supply (but the exact advent of which no one could actually foretell until it arrived), it seemed to me more prudent to turn one's attention to other things for the time, than to incur the risk of recommending work which might soon have to be undone.

I have always expected and looked forward to a time when there would be one system of lighting, with variations merely in details, and have felt that the rivalry between the two systems would some day end as the battle of the gauges ended in the early railway

days; and I think there are signs of the end now. It seems as if the narrow gauge would win again,—as if the tortoise would again beat the hare, though it is true that to do so the tortoise has had to improve its pace considerably. Mr. Addenbrooke.

The discussion on Mr. Addenbrooke's paper was adjourned.

The PRESIDENT announced that, as the result of the ballot, the following candidates had been elected:—

Members:

Robert Stuart Hampson.	Major R. M. Ruck, R.E.
Walter Osmond Rooper.	David C. Smith.

Associates:

John E. Addyman.	Richard Hamerton Hayne.
R. Stewart Bain.	Charles Keeble.
Lawrence Birks.	Sidney Edward Linsell.
Walter Henry Cooke.	Arthur Richard Peart.
Arthur Thomas Cooper.	John Pilling.
Oswald L. Falconar.	Percy Speedy.
Frederic Fowkes.	William Arthur Stevens.
John George Freeman.	Walter Jeffrey Targett.
Sam. Handford.	William A. Walton.

Students:

Leslie H. Andrews.	William P. L. Harrison.
Ernest William Bache.	James Fitz-James McKean.
C D. Braddon.	Alfred Mitchell-Withers.
Arthur Daniel Crowther.	Austin H. Peake.
Fred. Leslie Cruikshanks.	Ernest Henry Rogers.
Arthur Dangerfield.	Sydney John Roseblade.
Charles W. Eden.	Charles B. H. Stalvies.
Allan Edgar Eyears.	Edward Ernest Tasker.
William Ernest Few.	Robert Tervet.
Philip Henry Gibbs.	Thomas Julian Tolmé.
Ernest Joseph Greensmith.	James Welford.
H. G. Gridley.	F. H. Wilson.

The meeting then adjourned.

ORIGINAL COMMUNICATION.

A SIMPLE METHOD OF ANALYSING PERIODIC CURVES.

By E. BASIL WEDMORE, Student.*

No excuse is needed for bringing this subject before you this evening. The mathematical electrical engineer, in all problems dealing with alternating or other periodic currents, has to deal with forces and quantities that vary as some harmonic function of the time. We know that it is a common practice to assume that these variations follow a simple sine law. Where this is not admissible, many problems are quite insoluble, unless we use some method of analysing the law of variation into a series of simple sine functions, which can then be dealt with separately by the usual methods. We believe that there are many who avoid such calculations solely owing to their not being acquainted with any simple method of analysing harmonic curves, or owing to their not having the necessary instruments or apparatus for using one of the methods more generally known.

The curves of voltage, current, and magnetisation are to electrical machinery what the indicator diagram is to the steam engine; and we venture to believe that the solving of many problems depending on the peculiar form of these curves, such as the best form of curve for incandescent lighting, or transforming under various conditions, might be considerably simplified by studying the analysis of the curves. The analysis might form a half-way station at which the manufacturing and lighting engineers might meet; the one studying the qualitative effects of the various components on the apparatus that he uses, and the other studying the methods of producing the various components required.

* Paper read at the Students' Meeting, March 6th, 1896.

But to return to the subject of this paper. I propose, firstly, to enunciate the principle; secondly, to give examples of its application; and then to prove the method analytically and geometrically. Special attention will be given to those cases more immediately applicable to electrical problems, and to the effect of errors in the curve analysed. A few special cases will also be pointed out where rather interesting points arise.

It may be as well to point out at this juncture, in case any present are not acquainted with the fact, that Fourier has shown that any periodic function is the resultant of a number of simple harmonic functions, which, as we know, may be represented by sine curves. The object of the analysis is to find these component curves, their phase and amplitude.

It has been pointed out that the method about to be described is analogous in some respects to the use of chemical reagents in chemical analysis. Each application of the process separates out from the given curve those component sine curves whose periodicity is some simple multiple of the divisor or reagent used. Each of the prime numbers may be used as a reagent, and will separate out all those curves whose periodicity is some simple multiple of the number used.

For the application of this method it is necessary to obtain one complete period of the curve to be analysed. (It is hardly necessary to point out that one complete period must contain a whole number of periods of each component.) The method consists of a continual application of the following process:—

" Draw the curve so that the independent variable, say time, is " horizontal. Divide the curve vertically into any number of equal " parts, say N parts. Superpose the parts, and algebraically add " them."

The result will be another curve consisting only of those components whose periodicity, as compared with that of the original curve, is some simple multiple of N, all other components having been eliminated.

Thus in Fig. 1 we have one period of a curve, X, composed of four components shown above it, and numbered 1, 2, 3, and 4. The figure is divided into two parts (*i.e.*, N = 2), and in Fig. 2

the parts are superposed, their algebraical sum being shown in Fig. 3. Here it will be seen that curves 1 and 3, having one and three periods respectively, have been reduced to zero, 1 and 3 not being equal to N or a multiple of N; while 2 and 4, whose periodicities are respectively equal to N and a multiple of N, have been reproduced; with their amplitudes, however, doubled, or multiplied by N. The component curves, Nos. 1, 2, 3, and 4, are given only to show the effect of the process when applied to curve X, and have nothing to do with that application. We see that by operating on X with the number "2," we have obtained a curve Y, consisting only of those curves whose periodicity is some multiple of 2, with their amplitudes doubled. If, now, we reduce the amplitude of Y by one-half, we shall obtain a curve Z, which contains only half the components. For the complete analysis of the curve it would be necessary to proceed as follows, being careful always to reduce the amplitude of each curve obtained to its original value (*i.e.*, divide it by N) before operating with it :—

1. Divide Z into two parts and proceed as before, thus obtaining component 4, (having a periodicity = twice that of curve operated upon).
2. Subtract 4 from Z, and thus obtain 2. $(Z-4=2+4-4=2.)$
3. Subtract Z (that is, 2 and 4) from X, and you will obtain 1 and 3 combined $\{(1+2+3+4)-(2+4)=(1+3)\}$.
4. Divide this curve (1 and 3) into three parts and proceed as at first, and you will obtain No. 3.
5. Subtract No. 3 from 1 and 3, and you will obtain No. 1.

We have now obtained all the components, and each in its respective position with regard to the original curve.

Fig. 4 contains the complete analysis. The figure is complicated somewhat by the necessity of reducing the amplitude of curves when obtained by addition of ordinates, and the number of curves to be drawn has been increased by the necessity of spreading the analysis over three lines for the sake of clearness. If the work is done on a larger scale this is quite unnecessary.

The curves drawn in full, with the exception of the first one, are the result of a complete operation, the other curves being

intermediate steps. The dotted ones are curves re-drawn merely for convenience in superposition. (This is quite unnecessary after one has obtained a little experience.) The dot-and-dash curves are curves as first obtained, which require to have their amplitudes corrected. The curves are numbered in the order in which they are obtained.

Curve 2 is X superposed. Curve 3 is the same as Y, and curve 4 is Z, and contains all the even-numbered components. Curve 4 is bisected, and, the two halves being superposed, we obtain curve 6, which reduced by $\frac{1}{2}$, gives us 7, one of the components (No. 4, Fig. 1). Subtracting curve 7 from 9 (which is 4 reproduced), we obtain 10, the second component. We now return to the original curve and operate with "3." The parts are superposed on the right-hand side of the figure. Curve 13 is the algebraical sum, and 14 is 13/3, and is the 3rd component. Subtracting 16 (which is = 4) from 1, we obtain 17, which consists of components 1, 3, 5, &c. (the odd numbers). Subtracting 14 from 17, we obtain 18, which is the first component. We see that curves 18, 10, 14, and 7 are respectively similar in all particulars to Nos. 1, 2, 3, and 4, in Fig. 1. 24 ordinates were used in this analysis, but the lines have been left out for clearness. The first 12 are shown in Fig. 1. Of course squared paper might have been used.

By the use of a proportional compass, set to make the amplitude corrections, we might have left out all the curves except the six shown in full line, four of which are components; and in Fig. 10, which is the analysis of a transformer curve, to be again alluded to, we might have drawn the components straight away.

A very simple calculation explains the curious properties of periodic functions which enable us to obtain our results in this simple manner.

Let N = number of parts, and P = number of periods of any component.

We may write the P^{th} term of Fourier's series thus—

$$P^{th} \text{ term} = A_p \sin P \frac{2\pi}{T}(t + \phi_p).$$

After dividing the curve into N parts, the parts may be represented by the following :—

$$1\text{st} = A_\rho \sin P \frac{2\pi}{T}(t + \phi_\rho);$$

$$2\text{nd} = A_\rho \sin P \frac{2\pi}{T}\left(t + \frac{T}{N} + \phi_\rho\right);$$

$$3\text{rd} = A_\rho \sin P \frac{2\pi}{T}\left(t + \frac{2T}{N} + \phi_\rho\right);$$

$$\text{last} = A_\rho \sin P \frac{2\pi}{T}\left(t + \frac{(N-1)T}{N} + \phi_\rho\right).$$

We note that each term differs (in phase) from the preceding one by an equal amount—

$$P\frac{2\pi}{T} \times \frac{T}{N} = 2\pi\frac{P}{N}.$$

The sum of these expressions, which, of course, represents the resultant of the superposition, is as follows :—

$$\Sigma_\rho = A_\rho \frac{\sin P\pi}{\sin \frac{P}{N}\pi} \sin P \frac{2\pi}{T}\left(t + \frac{N-1}{N} \cdot \frac{T}{2} \cdot + \phi_\rho\right).$$

The coefficient of frequency with respect to that of the original curve—namely, P,—being always a whole number, the factor

$$\frac{\sin P\pi}{\sin \frac{P}{N}\pi}$$

will be zero, except where $\frac{P}{N}$ is also a whole number (*i.e.*, except when $P = N$ or a multiple of N), in which case the factor takes the form $\frac{O}{\frac{O}{N}}$, the resolution of which leads to the value $\pm$ N.

If it is $-$ N, then the right-hand part of the expression will also be negative; therefore their product or the whole expression will still be positive.

We may see also that in the case where $\frac{P}{N}$ is a whole number, the factor $P\frac{2\pi}{T} \cdot \frac{N-1}{N} \cdot \frac{T}{2}$, in the right-hand side, which, simplified,

becomes $\frac{P}{N} \cdot (N-1)\pi$, will be a simple multiple of π, having no effect on the expression, as $\sin k\pi =$ zero, if k is a whole number; we may therefore eliminate it. Finally, then, we see that when P is not a simple multiple of N, the sum is zero; but when P is a simple multiple of N, making $\frac{P}{N}$ a whole number, the expression for the sum becomes

$$N A_p \sin P \frac{2\pi}{T}(t + \phi_p),$$

which is exactly the same as the original curve, except that its amplitude is multiplied by N, the number of parts.

We note that the phase has not been altered.

For the benefit of those who may have found some difficulty in following the analytical proof, we propose now to give a proof by means of the clock diagram.

We see that in performing the superposition we are really superposing a number of curves differing only in phase. We might take any number of periods of the original curve and superpose the whole upon itself either graphically, analytically, or by the clock diagram, N times, differing by $\frac{1}{N}$th of a period in phase. The result would be just the same.

Thus in the analytical proof just given we see that the expressions representing the several parts are really expressions representing not only a short length of curve, but any number of periods of a periodic curve; and the proof given holds good whether we only take parts of a period, as in the figure, or whether we take any number of periods.

Now we know that we may represent any given combination of sine functions by vectors in a clock diagram, the lengths of the vectors representing amplitudes, and the angles between the vectors and some fixed line passing through the same centre representing the lags and leads. We know also that, if these vectors are projected on to a line at right angles to this fixed line, the lengths of the projected portions will give us at any moment the instantaneous values of the quantities represented by

the vectors. One period of either component will be represented by one revolution of the corresponding vector, therefore one complete period of the combination will be represented by one revolution of the first component, two of the second, three of the third, &c.

Fig. 5 shows a vector, O A, and "a" is its instantaneous value. O Y is our fixed line. If the figure was drawn at time 0, then $\sin^{-1} a =$ angle of lead.

Fig. 6 contains a vector one revolution of which gives us one period. The period has been divided into three equal parts, and the curves to be superposed are represented by the vectors I, I_a, and I_b, which we see differ in phase by one-third of a period. Now, according to our rule, as 1 is no multiple of 3, the quantity should cancel; and we see that it does so, whether we resolve the diagram by the parallelogram of forces or by projecting on to a fixed line. The projections are shown, and marked a, b, and c, and it is evident that $b + a - c =$ zero. If we had taken three periods—that is, three revolutions—and divided into three parts, the parts would have been coincident, and our vector would have been trebled; and our rule says that, as 3 is a multiple of 3, ($P = 1 \times N \times 1$), the resultant will be a curve of the same periodicity and phase, but of three times the amplitude of the original curve.

Fig. 7 represents the curve X in Fig. 1 at time 0; also the result of the first operation; and we see that, while 1 and 3 are cancelled, 2 and 4 are doubled.

Fig. 8 represents a combination divided into three parts, with the expected result.

The clock diagram cannot, of course, be used for analysing the curve, as we cannot draw the vectors until we know the components. A certain artifice may be used, however, in certain cases, which will enable us to construct the clock diagram directly from the curve. (See Appendix.)

The curves obtained from alternators and transformers present a peculiar form of symmetry. The positive and negative portions of the curve are exactly similar in shape. This must be so from the symmetry of the apparatus producing the curve. If the north

poles of an alternator were shaped differently from the south poles, we should then have an unsymmetrical curve. Perhaps some enterprising individual may yet show that this is the best arrangement. There is, at any rate, a very great difference between the components of a symmetrical and an unsymmetrical curve, in so far as that the one consists solely of components whose periodicity is an odd number as compared with the original curve, while the components of the other must be even, or odd and even. This will be comprehended at once on inspecting Fig. 10, where we see that if the curve (No. 1) were bisected and superposed the result would be zero, showing that there cannot be any components with periodicity $= 2$ or a multiple of 2.

If, as in Fig. 11, No. 2, we obtain looking-glass symmetry—*i.e.*, the positive or negative parts symmetrical in themselves—then there can be no difference of phase between the component curves. Where, as in Fig. 11, there are only two components, the vertical height, measured one-quarter period from zero, equals the sum or difference of the components, and the mean ordinate multiplied by $\frac{\pi}{2}$ equals the principal ordinate $\pm \frac{1}{\mathrm{P}}$ times the Pth ordinate; from which equations we may obtain both components.

With regard to the effect of errors in working the method, or of errors in the original curve, there are several points to be noted. Firstly, if we could remove the components from the curve and leave behind only the errors, these would form a curve of irregular form, which might, nevertheless, be analysed into a number of component sine curves of various periodicities. As the curve would be very irregular, a great many components would be required to accurately represent it; however, the point is that in this error curve there is a component of periodicity $= 1$ (its value might, of course, be zero), there is a component of periodicity $= 2$, of periodicity $= 3$, &c. The amplitudes of these components may be small in comparison with that of the error curve, and $\therefore$ very small with respect to those of the original curve. Now, when we analyse the original curve, it is evident that the component of the error curve of periodicity $= 2$ will be removed with the component

of the original curve of periodicity = 2; and so with any other component: each component we separate from the original curve will be erroneous to the extent of the component of the same periodicity of the error curve. But what of the other components? Let us consider the first 24 only, and assume that we have analysed the curve to the 6th: then we have 18 to consider. Now nine of these will disappear, as we can easily show. Fig. 12 contains two curves, No. 2 having twice the periodicity of No. 1. If 1 and 2 were added, we should add to the positive part of No. 1 just as much as we subtracted from it, and the same with the negative part; in other words, the area would remain unaltered. If, therefore, we take any curve containing errors whose periodicity is an even multiple of that of the curve, these errors will be eliminated by drawing a smooth line through the inequalities—*i.e.*, keeping the area the same—or by finding the amplitude by taking $\frac{\pi}{2}$ times the mean ordinate. Therefore all even-numbered ordinates in the error curve disappear. With regard to the others, let us consider the 7th. As it is a prime number, it would appear in the first component. If its zero coincides with that of that component, then the effect will be that the area of each half of the curve will be increased or diminished by an amount equal to that of one-half period of the error component. If the maximum of the error curve coincides with the zero of the other, then the areas will not be altered, and the error will cancel. The probable error per ordinate will be about $\frac{5}{3}$rds of $\frac{1}{7}$th of the mean ordinate of the error component.

The same reasoning applies to the other components, the particular curve they appear in depending on what number their periodicity is a multiple of.

We find, therefore, that the error in any one ordinate of any component will probably be much less than the mean error in the ordinates of the original curve. In fact, if we analyse an erroneous curve, and then reconstruct it from its components, its last state is much better than its first.

If, on the whole, the positive errors are greater than the

negative, or *vice versâ*, then the difference will be removed with the constant term.

It is essential in this method, as in others, that the constant term, if there be one, be eliminated at the outset. There rarely is one, however.

To give a practical illustration; I have the analysis of a curve that might have been taken from a transformer. The mean error in the ordinates is 2 per cent. There are two components. The mean error in the smaller one is $\frac{1}{2}$ per cent., in the larger $\frac{1}{4}$ per cent.; and, as these components are themselves smaller than the original curve, it is evident that most of the errors have been removed. It is possible, by performing the analysis arithmetically instead of graphically (by writing down the ordinates in figures and performing the operation on them arithmetically), to reduce the error to smaller proportions, even if only working to two significant figures.

We might point out that, if there is a large error in one or more ordinates, it will be spotted at once while working.

With regard to the arithmetical method of performing the analysis—which is the most accurate where it can be applied—the procedure is the same as that used in the graphical application.

We give below the complete analysis of the curve X, Fig. 1, to correspond with Fig. 4; also the analysis of curve No. 1, Fig. 10, showing the method of finding phase and amplitude. You will see that it only takes seven columns of figures to separate four components; and, as three columns are taken up by the question and answer, one can hardly consider the method a slow or tedious one.

If the curves are plotted to a large scale on squared paper, and a proportional compass is used, the work may be done very rapidly. It has already been pointed out that in Fig. 10 the answer might have been written down straight away; and when we consider that 15, or even 9, ordinates would have given us fairly accurate results, we see that the work of analysis by this method is reduced to a minimum.

The number of ordinates taken must be a multiple of the periodicities of all the components we wish to separate, and we must have at least three points per period of any curve we wish to

find, as two points leave both amplitude and phase indeterminate. This, however, is not very serious. In electrical problems 15 ordinates will suffice to find the 1st, 3rd, and 5th components, and if we wish to find the 7th we must redivide our curve. When a small number of ordinates are taken, it is best that their number shall be an odd multiple of the periodicities of the components to be separated.

	A	B	C	D	E	F	G	H
Time.	Original Curve.	A superposed.	A + B.	C/2 = Comp. 2 and 4.	D superposed.	D + E.	F/2 = Comp. 4.	D − G = Comp. 2.
0	5·63	−5·17	0·46	0·23	3·71	3·94	1·97	−1·74
1	5·79	−4·01	1·78	0·89	0·47	1·36	0·68	0·21
2	4·81	−3·03	1·78	0·89	−3·47	−2·58	−1·29	2·18
3	5·24	−2·06	3·18	1·59	−5·53	−3·94	−1·97	3·56
4	7·97	−1·35	6·62	3·31	−4·67	−1·36	−0·68	3·99
5	11·20	−1·90	9·30	4·65	−2·07	2·58	1·29	3·36
6	11·89	−4·47	7·42	3·71			1·97	1·74
7	8·73	−7·79	0·94	0·47		G continued downwards.	0·68	−0·21
8	2·77	−9·71	−6·94	−3·47			−1·29	−2·18
9	−2·94	−8·12	−11·06	−5·53			−1·97	−3·56
10	−6·06	−3·28	−9·34	−4·67			−0·68	−3·99
11	−6·39	2·25	−4·14	−2·07			1·29	−3·36
12	−5·17				−2·34	0·23	−5·40	−3·07
13	−4·01			L continued upwards.	−0·31	0·89	−4·90	−4·59
14	−3·03				1·87	0·89	−3·92	−5·79
15	−2·06				2·98	1·59	−3·65	−6·62
16	−1·35	2·77	5·63	7·05	2·35	3·31	−4·66	−7·01
17	−1·90	−2·94	5·79	0·95	0·32	4·65	−6·55	−6·87
18	−4·47	−6·06	4·81	−5·62	−1·87	3·71	−8·15	−6·31
19	−7·79	−6·39	5·24	−8·94	−2·98	0·47	−8·26	−5·28
20	−9·71	−5·17	7·97	−6·99	−2·33	−3·47	−6·24	−3·91
21	−8·12	−4·01	11·20	−0·83	−0·31	−5·53	−2·59	−2·28
22	−3·28	−3·03	11·89	5·62	1·87	−4·67	1·39	−0·48
23	2·25	−2·06	8·73	8·92	2·97	−2·07	4·32	1·35
	Original Curve.	A superposed.	A superposed.	A + I + J.	K/3 = Comp. 3.	D repeated.	A − D = Comp. 1 and 3.	N − L = Comp. 1.
	A	I	J	K	L	M	N	O

The complete analysis of a curve of four components.

It will be seen that as columns B, E, I, J, and M, and parts of G and L, are only written so that figures may be added or subtracted conveniently; they are unnecessary. The fingers of the left hand may be used to mark the figures to be operated on. Thus, by putting the thumb and first finger on lines 0 and 12, in column A, and slipping them down one line at a time while adding, we can write column C without first writing column B, which is merely A repeated from line 12 downwards.

A	B	C	D	E	F	
Original Curve.	A superposed.	A superposed.	A + B + C.	$D/_3 =$ Comp. 3.	A − D = Comp. 1.	
5·0	5·8	− 5·1	5·7	1·9	3·1	
7·5	0·4	− 4·6	3·3	1·1	6·4	
3·7	− 8·0	− 4·7	− 9·0	− 3·0	6·7	
5·8				1·9	3·9	
0·4				1·1	− 0·7	
− 8·0				− 3·0	− 5·0	
− 5·1				1·9	− 7·0	
− 4·6				1·1	− 5·7	
− 4·7				− 3·0	− 1·7	
			Sum	18·0	40·2	
			Mean ordinate	2·0	4·5	
			Mean ord. $\times \frac{\pi}{2}$	3·14	7·06	− amplitudes.

First ordinates 1·9 and 3·1

Reduced to unit amplitude 0·633 and 0 443

$$\sin^{-1} 0{\cdot}633 \text{ and } \sin^{-1} 0{\cdot}443$$

$$= 39^\circ \qquad = 26^\circ$$

$$39^\circ/_3 = 13^\circ$$

Complete analysis of transformer curve (see Fig. 10).

In the above, the correct values for the amplitudes are 3 and 7, so small errors have crept in owing to our using only two figures and nine ordinates. The phase, however, is correct. $\sin^{-1} 0{\cdot}633$ gives us 39°; but, as this component has three periods to one of the original curve, we must reduce this lead by one-third to make it comparable with the other.

ABSTRACTS.

P. BOUCHEROT—SYNCHRONOUS AND NON-SYNCHRONOUS ALTERNATING-CURRENT MOTORS.

(L'Éclairage Électrique, Vol. 5, No. 44, p. 193.)

The author criticises a controversy which has lately taken place with reference to the above, and which ended in favour of the synchronous motor.

In a communication to *L'Industrie Électrique*, 25th December, 1894, M. Kolben, of Oerlikon, arrives at the conclusion that, although the power-factor is always higher in the case of a synchronous motor, its output is, however, lower than that of the non-synchronous motor.

M. Picou, in a communication to the Société des Électriciens (6th February), on the transmission of power by alternating synchronous motors, arrives at the opposite conclusion, and is supported by M. Blondel.

The author makes the following comparison between the efficiency, starting power, and lag in the two machines:—

Efficiency.—This question is of greater theoretical than practical importance, as a difference of 2 or 3 per cent. in the efficiency will not have any serious effect on the behaviour of the motor. It is erroneous to believe that the efficiency of a non-synchronous motor can be increased by converting it into a synchronous motor. The opposite result is obtained, for it is not merely sufficient to replace the ampere-turns on the motor produced by slip, by an equivalent number of continuous ampere-turns. The synchronous motor thus obtained would not work properly, and would easily fall out of step.

The author compares the non-synchronous motor, with a synchronous motor in which the exciting ampere-turns are produced by the alternating source, and the compensating reactive ampere-turns by the squirrel cage, but with the advantage for the former that the reactive ampere-turns vary automatically with the load. The non-synchronous motor behaves within similar limits of speed as a synchronous motor the exciting power of which would vary automatically with the resisting torque—not through small limits, as in the case of so-called compound alternators; but through wide limits, on account of the large reaction which a synchronous motor, would have when working under non-synchronous conditions. These conditions cannot, however, be realised, on account of the self-induction of the field circuit, which would prevent the exciting force from varying as rapidly as the torque. The only method of satisfactorily converting a non-synchronous motor into a synchronous motor is to make a considerable increase in the air gap, which produces a corresponding increase in the excitation, and thus reduces the reaction to about the same value as in a good synchronous motor. The author considers the case of a non-synchronous motor absorbing 20 kilowatts at 2,000 volts with a power-factor of 0·85: it then requires 11·8 amperes; with a resistance of 7 ohms

975 watts will be lost, and in a commercial motor of this output the squirrel cage absorbs about 2 per cent., or 400 watts. To convert this into a synchronous motor it would be necessary to lose about 6 per cent. in excitation, or about 1,200 watts. The relation then works out as follows :—

	Non-Synchronous.	Synchronous.
Ohmic loss in the circuit receiving the alternating current	795 watts.	755 watts.
Ohmic loss in the isolated circuit ..	400 ,,	1,200 ,,
Useful brake power	18,000 ,,	18,000 ,,
Total power received	19,375 ,,	19,955 ,,
Efficiency, neglecting the iron loss ...	0·93	0·90

The following is a practical case corresponding to the conversion of a two-phase Brown motor of about 20 H.P. :—

	Non-Synchronous.	Synchronous.
Ohmic loss in the circuit receiving the alternating current	400 watts.	300 watts.
Ohmic loss in the isolated circuit... ...	300 ,,	1,000 ,,
Iron loss	700 ,,	700 ,,
Useful brake power	15,000 ,,	15,000 ,,
Total power supplied	16,400 ,,	17,000 ,,
Commercial efficiency	0·915	0·883

The above difference of 3 per cent. in the efficiency reaches 8 per cent. at half load, and 12 per cent. at quarter load.

In the case of the 20-H.P. motor above mentioned, there would have only been space enough for one-quarter or one-fifth of the right amount of field wire by replacing the squirrel cage with an iron core; and it would then have been necessary to use a separate exciter. The use of eddy-current circuits for damping variations in the field, cannot alter these conditions. Although their theory has only lately been published by Messrs. Hutin and Leblanc, their action has always existed in alternators, for the field magnet, consisting of a large number of turns of copper, would act in this manner. The result is the same whether the circuit consists of one turn with a section S, or of N turns with a section S/N. The damping action, therefore, only depends on the weight of copper employed. The solid metal in the magnets, and the closed circuit of the magnet formers, also act in this manner. The author states that the effect of a closed circuit for damping variations of the field will not prevent a motor from falling out of step, this takes place with motors having too great a reaction, and without an appreciable variation of the speed. A variation of speed of 1-1,000th in a 40-∿ motor may produce a falling out of step after 6 or 8 seconds if the synchronising effects due to the mutual action of armature and field are incapable of stopping it.

Starting.—It has been stated that a synchronous motor provided with damping circuits in the field magnets would start as well as a non-synchronous motor. This would, no doubt, be the case if the non-synchronous motor were converted into a synchronous motor without increasing either the air gap or the excitation; but even under these conditions the results would prove unsatisfactory. The author

considers it impossible that the synchronous motor should start as well as the non-synchronous motor; for the obtaining of such a result would be to jeopardise the good working of the motor when synchronised.

Lag.—With respect to the lag between current and voltage, the synchronous motor has a distinct advantage over the non-synchronous motor; for with proper variation of the field the former produces no lag, whereas the latter produces a lag of at least 30°. It is well known that for two reasons a non-synchronous motor reacts more strongly on a generator than an equivalent number of lamps. The power-factor being about 0·85, the generator will then have to give about 15 per cent. more power if only motors be used; the drop in the main will be increased by 15 per cent. If, however, the load be equally divided between motors and lamps, the increase in power will only amount to 3 per cent.

The armature reaction of a well-designed alternator should not be much increased by the lag. Mr. Lahmeyer stated that at Bockenheim he was able to increase the output of the generators by nearly 50 per cent. by eliminating lag. This indicates that the generators have too great a reaction, and a general conclusion should not be drawn from this.

With a well-designed alternator the only advantage in suppressing lag is an increase of 15 per cent. in the output. In the case of a system in which house transformers are employed, the question of lag may become of greater importance. A 1,000-kilowatt plant may have to supply 200 to 300 kilowatts for magnetising transformers. In order to prevent this apparent loss of power, it has been suggested to compensate the lagging current by an advancing current, by employing over-excited synchronous motors. The author considers that these could never fulfil these conditions, as in the above case it would be necessary to employ a motor load of 800 to 1,000 kilowatts, and the loss due to over-excitation only, would prohibit their use. The author believes that condensers will eventually be used for this purpose.

In conclusion, the objections prohibiting the use of synchronous alternating-current motors in preference to non-synchronous motors are—(1) Their lower efficiency; (2) greater difficulty in starting; (3) greater complications, and consequent care.

E. LEYST—ON THE MAGNETISM OF PLANETS.

(Journal de Physique, Vol. 5, January, 1896, p. 33.)

Investigations made at St. Petersburg and Pawlowsk, from 1878 to 1889, on the influence of the different planets on the magnetic declination, give results which show that all the planets exert a marked action, not only on the absolute value of the declination, but also on its diurnal variation. All the planets, with the exception of Mercury, when close to the earth, increase both the absolute value of the declination and the periodic portion of its diurnal variation. The extreme values of the declination during the year vary by 0·85′. The author compares the amplitude of variation corresponding to an entire synodic revolution of

each planet with this amplitude, A, and expresses it as a function of A taken as unity. The following are the values obtained :—

Mercury	0·58
Venus	0·61
Mars	0·59
Jupiter...	0·40
Saturn	0·12
Uranus...	0·15
Neptune	0·27

In an appendix on this memoir, the author studies the influence of Mercury on the horizontal, vertical, and total magnetic intensities, and also on the inclination.

M. MAURAIN—ON THE FUSION OF METALLIC WIRES BY CONTINUOUS CURRENTS OR BY THE DISCHARGE OF A BATTERY.

(*Bulletin de la Société Internationale des Electriciens, Vol.* 12, *No.* 123, *p.* 439.)

The formation of small globules at the surface of wires, partially fused by the discharge from a battery, is generally attributed to the localisation of the current at the surface of the wire, due to the oscillatory nature of the discharge. The author has, however, obtained the same effects by bringing the wires to their fusing point by means of a continuous current from a circuit of large or small self-induction. The small drops were seen to form clearly on the surface of the wire. The cause of the formation of these drops may be due to the capillary phenomena produced during fusion, analagous forms existing in Plateau's equilibrium figures, of a liquid in a state of suspension in another liquid of the same density.

It is, however, difficult to ascertain whether the figures obtained in the fusion of wires are equilibrium forms or unstable forms arrested in their transformation by solidification.

When operating with wires of different diameters, the product of the number of globules per centimetre, and of the diameter of the wire, varies only through small limits. The results obtained are as follows :—

Material.	Diameter. Mm.	Number per Centimetre.	Product.
Copper	0·92	17·3	0·159
Phosphor-copper ...	0·145	10·2	0·148
Iron	0·16	8·6	0·138
Copper	0·25	7·3	0·182
Steel	0·282	4·3	0·164
Copper	0·4	4·5	0·18

H. BAGARD—THE HALL PHENOMENON IN LIQUIDS.

(*Comptes Rendus, Vol.* 122, *No.* 2, *p.* 77.)

Hitherto the Hall phenomenon has only been observed in metals. The experiments made by Mr. H. Roti (*Journal de Physique,* 2nd series, vol. ii., p. 514,

1883) led him to believe that the Hall effect was not produced in liquids. The author has, however, found that the phenomenon takes place in solutions to a large degree. He found that a very weak magnetic field produces a marked deviation of the equipotential lines in a layer of liquid of a relatively great thickness (1·6 mm.) carrying a current of only a few hundredths of an ampere. The layer of liquid was placed horizontally, and was of rectangular shape, having sides 53 mm. × 30 mm., and consisted of a saline solution. The electrodes consisted of the same metal as that in solution.

For measuring V the capillary electrometer was employed as a zero instrument. In order to prevent irregularities in the temperature of the solution, the bath, &c., was surrounded by water maintained at a constant temperature.

The magnetic field was produced by an electro-magnet having two square horizontal pole-pieces producing a nearly uniform field. The liquids employed consisted of recently boiled solutions of sulphate of zinc and sulphate of copper of various densities. The longitudinal current was obtained from Daniell cells, and amounted to 0·019 ampere and 0·37 ampere. The field was varied only through 300 to 400 C.G.S. units. In all the cases dealt with, the deviation of the equipotential lines of force takes place in the same direction as with bismuth. The deviation is at first rapid, and then slowly reaches its final value, which takes place at the end of two or three minutes with a very concentrated solution. With a weak solution the deflection is greater, and, instead of becoming steady in two or three minutes, it continues to increase with the duration of the magnetic action; but this point has not yet received close attention. When the magnet is removed the deflection returns to its initial value after two or three minutes—rapidly at first, and then more slowly. The following are the results of two experiments made with two solutions of sulphate of zinc of very different strength; sulphate of copper yields very analagous results:—

A. Solution of sulphate of zinc containing four equivalents of salt per litre of water:—

Strength of longitudinal current ... ... 0·036 to 0·037 ampere.
Strength of magnetic field ... ... 300 C.G.S. units.
Initial value of $\mathrm{V}\,a - \mathrm{V}\,b$ ... ... $d = 0{\cdot}0865$ Daniell.

B. Solution of sulphate of zinc containing 0·5 equivalent of salt per litre of water:—

Strength of longitudinal current ... ... 0·020 to 0·022 ampere.
Strength of magnetic field ... ... 380 C.G.S. units.
Initial value of $\mathrm{V}\,a - \mathrm{V}\,b$ ... ... $d = 0{\cdot}1461$ Daniell.

In order to form some idea of the magnitude of the Hall effect in these liquids, the author calculated approximately the ratio of the angle of deviation of the equipotential line to the strength of field, in C.G.S. units, producing this deviation. The value 23×10^{-7} was obtained for the solution A, and 133×10^{-7} for the solution B. The latter figure particularly, is of the order of those obtained by Mr. Leduc for the samples of bismuth which he has studied, and, as is known, the Hall effect is several thousands of times greater in this than in most other metals.

J. VIOLLE—AN ACETYLENE PHOTOMETRIC STANDARD.

(*Comptes Rendus, Vol.* 122, *No.* 2, *p.* 79.)

The use of flames as standards possesses many advantages from a practical point of view. A gas of invariable chemical composition, burning under definite conditions, may be of service as a secondary standard of light.

Mr. Blondlot's studies on acetylene have demonstrated the use of this gas for the above purpose.

Mr. Moissan has shown how the pure gas can be prepared by the simple action of water on carbide of calcium, the latter being prepared in the electric furnace. If acetylene be burnt under a rather high pressure in a large flat flame, one obtains a light of great brilliancy, steadiness, and illuminating power, and of uniform intensity over a fairly large surface By placing a screen having a given sized aperture in front of the flame, a convenient source of light is obtained for ordinary photometric measurements. In the lamp used by the author the acetylene is admitted from a small conical orifice into a tube where the gas is suitably mixed with air, and which is fitted with a steatite burner as is used for ordinary gas. Either the whole or part of the flame can be employed, which, in the lamp designed by the author, can be regulated by means of an iris diaphragm, or by previously calibrated apertures. The whole flame is equivalent to more than 100 candles, under a pressure of 0·30 m. of water. The consumption of acetylene is then 58 litres per hour. The illuminating power is then six to eight times greater than with coal gas. The spectro-photometer shows that through the whole spectrum from C to F the acetylene light differs but little from that of platinum in fusion, which is used for defining the absolute standard, and from which the standard candle is derived, this being equivalent to 1-20th of the absolute unit.

J. PERRIN—SOME PROPERTIES OF THE RÖNTGEN RAYS.

(*Comptes Rendus, Vol.* 122, *No.* 4, *p.* 186.)

The author considers that the rays employed in Mr. Röntgen's experiments are not cathode rays, as these could not pass out of a vacuum tube unless the glass were of extreme thickness, whereas the Röntgen rays easily pass through a thickness of 1 mm. The author has made several experiments on the degree of opacity of various substances. Wood, paper, wax, paraffin, water, appear very transparent. Then come the following substances, arranged in the order of increasing opacity:—Carbon, bone, ivory, spar, glass, quartz (parallel or perpendicular to the axis), rock salt, sulphur, iron, steel, copper, brass, mercury, lead. A law has not yet been found applicable to the phenomenon; it is, however, remarkable that metals are generally less transparent than other substances, but have not the absolute opacity which they present to light. The author investigated whether the radiation is well defined, or, in other words, whether the propagation is rectilinear. In order to determine this, two circular diaphragms of brass, a few centimetres apart, were placed in front of the tube; on a sensitive plate placed a little further away was obtained a well-defined image with umbra and penumbra, the dimensions of the spot conforming with the hypothesis of a rectilinear propagation.

An experiment was then made to reflect a pencil of Röntgen rays defined by two 0·5 mm. slits placed 4 cm. apart. The pencil of rays was made to fall on a polished steel mirror, from which it would have reflected on to a photographic plate. No impression was observed after one hour's exposure. The experiment was repeated with a flint mirror, and with seven hours' exposure no result was obtained. An attempt was made to refract the rays, and for this purpose a 20° paraffin prism was interposed to the rays, and a 20° wax prism was also used. The two parts of the pencil should have given distinct images if refraction had taken place; this, however, was inappreciable, and certainly did not amount to more than 1°. An attempt was next made to form diffraction fringes. The actinic part of the tube was placed before a very narrow slit; 5 cm. further was placed a 1-cm. slit, and at a distance of 10 cm. from this was placed the dark slide containing a positive plate. The exposure lasted nine hours. A very sharply defined image was obtained without any fringe. Exactly in the same position as the above, was placed a second plate in an open slide, exposed to the green light emitted from the tube: a similarly shaped image was obtained, but possessing a fringe. If the phenomenon is periodic, the period is inferior to that of the green light employed. The above experiments prove the rectilinear propagation of Röntgen rays.

K. ÅNGSTRÖM—ON A SIMPLE METHOD OF PHOTOGRAPHICALLY REPRESENTING THE INFRA-RED SPECTRUM.

(Journal de Physique, Vol. 5, January, p. 32.)

In 1894, Mr. Langley published a method for automatically obtaining photographic records of the infra-red spectrum. The author suggests the following, as a substitute for Mr. Langley's somewhat complicated, although accurate, method. On an arm, A, of a good theodolite is fixed a light horizontal movable arm, D E, to which is fixed the tube, C, of a bolometer. To the extremity of the arm is fixed the dark slide containing the photographic plate, placed in a horizontal position; and almost perpendicularly above the plate is fixed the galvanometer, G, employed in conjunction with the bolometer. The light emitted from a slit falls at an angle of 45° on the mirror of the galvanometer, is then reflected vertically, passes through a lens, and the image of the slit is then formed on the photographic plate. By the deflection of the galvanometer mirror, this image moves in the sense of the bolometer arm—that is to say, perpendicularly to the sense of the displacement impressed on the plate by the motion of the arm. When making an experiment the arm D E is moved by clockwork, operated by a falling weight. On the photographic image the abscissæ will represent the deviations, and the ordinates the spectrum intensities. The greatest velocity of displacement employed in these experiments was 10 minutes of an arc per minute. The distance of the plate from the theodolite was 2 metres, so that a displacement of 1° of the tube of the bolometer corresponded to an arc of 3·48 centimetres. The author has applied this method to the study of the infra-red spectrum of the Bunsen burner produced by a rock-salt spectrum. He observed—(1) Two faintly marked

maxima, corresponding to 1·48 μ. and 1·96 μ., already pointed out by M. Paschen; (2) two well-marked maxima already observed by M. Julius, and of which the length of wave is 2·80 μ. and 4·34 μ.

G. QUINCKE—ON THE DURATION OF THE ELECTRIC SHADOW IN SOLID AND LIQUID INSULATING SUBSTANCES.

(Journal de Physique, Vol. 5, January, p. 28.)

The phenomenon of the electric shadow was first observed by A. W. Wright. The following is the method employed by the author in his observations:—

The exciter of a two-plate Holz machine is used without its condenser, and consists of a conical point, and disc 20 cm. in diameter, and 8 cm. apart, and between which a brush discharge takes place. The face of the disc is covered with white silk, which adheres to its surface directly electrification takes place. In the dark is observed a uniform greyish-blue luminous spot, about 5 cm. diameter, in the centre of the disc. If a dielectric be placed midway between the disc and the point, its shadow appears in the centre of the luminous spot, and disappears at the end of a short time. The dielectric is then turned 180° around a vertical axis; the shadow then reappears, and finally disappears. The author measures the time between appearance and disappearance by means of a metronome. This time represents the total duration of the electric phenomenon connected with the reversal of polarisation of the dielectric. A *resumé* in the form of a table is given of the somewhat complicated results observed by the author, which appear to conform to no particular law.

— MASCART—THE RESISTANCE OF CONDUCTORS TO ALTERNATING CURRENTS.

(Bulletin de la Société Internationale des Electriciens, Vol. 12, No. 123, p. 435.)

It is well known that alternating currents, instead of distributing themselves uniformly over the section of a conductor, tend to flow near the surface, on account of mutual induction. This effect increases with the frequency, and with the diameter of the conductor.

The general expression representing the distribution of alternating currents in a cylindrical conductor is

$$M = 4\,\pi\,\eta\,c\,\omega = 8\,\pi^2\,\frac{M\,C}{\tau},$$

in which η represents the magnetic permeability of the metal, C its conductivity, and τ its period of oscillation. The author refers to the work done by Lord Kelvin on the subject.

Assuming that the conductor has a solid section, and that $I_0 \sin \omega t$ is the value of the intensity of the axial current through unit section, then at any given point the value of the current ω is represented by

$$\omega = I_0\,A \sin(\omega t + \alpha) \qquad \dots \quad \dots \quad \dots \quad (1)$$

The value of A and α are functions of the x and y co-ordinates of the point considered, the value of ω having to satisfy a different equation.

If $d\,s$ is an element of section, the total current is then

$$I = \int u\,d\,s = I_0\;B \sin(\omega\,t + \beta) \quad \ldots \quad \ldots \quad \ldots \quad (2)$$

the quantities β and B being defined by integrals extended over the whole section. The mean square of the current ω being $\frac{I_0{}^2\,A^2}{2}$, the production of heat will then be more or less confined to the outside layers. If the resistance per unit section be, $\frac{1}{C}$, the effective, or ohmic, resistance of the conductor is

$$R = \frac{W}{I^2} = \frac{1}{C\,\beta^2}\int A^2\,d\,S \quad \ldots \quad \ldots \quad \ldots \quad (3)$$

As the normal resistance of R_0 of the conductor, relative to continuous currents, is the inverse of the product C s, then

$$\frac{R}{R_0} = S\int\frac{A^2\,d\,s}{B^2} \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (4)$$

When the section of the conductor is a circle of radius A, then the problem resolves itself into Fourrier-Bessel functions. Lord Kelvin has published a table of functions applicable to all conditions of the phenomena for a certain number of values of the variable, and complete enough to allow of interpolation. The author gives tables based on simple formulæ, and applicable with sufficient accuracy to most cases in practice. If the values of (4) be represented graphically, it is observed that the ordinates remain equal to unity as long as p does not exceed 2; when $p > 3$, the curve merges into a rectilinear asymptote, and the following expression is approximately correct:—

$$\frac{R}{R_0} = \frac{\sqrt{3}}{4}\left(p + \frac{3}{4}\right) \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (5)$$

The same character is found in the differences of phase α and β, which are at first 0, and can be represented as soon as the variable exceeds 3 by the expressions,

$$\left.\begin{aligned} \frac{\alpha}{\pi} &= 0{\cdot}2253\,(q - 0{\cdot}58) \quad \ldots \quad \ldots \quad \ldots \quad \ldots \\ \frac{\beta}{4} &= 0{\cdot}2244\,(p - 1{\cdot}60) \quad \ldots \quad \ldots \quad \ldots \quad \ldots \end{aligned}\right\} \quad (6)$$

With regard to the factors A and B, which determine the differences of amplitude of the current ω and of the total current I, they maintain fairly constant values as long as the variable is below 2, and they then increase much more rapidly. Beyond this limit they may be represented by exponentials of which the exponents are functions of the variable. For copper conductors the equation (5) then becomes—

$$\frac{R}{R_0} = \frac{\sqrt{2}}{2}\left(\frac{a}{9\sqrt{\tau}} + \frac{3}{8}\right) = 0{\cdot}707\left(\frac{a}{9\sqrt{\tau}} + 0{\cdot}375\right).$$

As long as the perimeter p is below 3 the resistance is not much altered, and there would be no advantage in using hollow tubes. If 49 periods per second were adopted, the diameter corresponding to $p = 3$ is $2\,a = \frac{9}{7}\,3 = 3{\cdot}9$ cm. For thinner conductors the resistance can be calculated as for continuous currents. In telephone work the frequency would be about 900; the diameter relative to $p = 3$ then becomes $2\,a = \frac{9}{30}\,3 = 0{\cdot}9$ cm., which is also thicker than is usually employed

in practice. The author points out that in the value of the coefficient, m, the conductivity, C, is multiplied by the magnetic permeability. The iron wires should therefore be more conducting to alternating currents, all things being equal. This explains the results of an experiment by Melsen which otherwise might appear a paradox:—

If a continuous current be sent through two parallel wires of the same diameter, one being of iron and the other of copper, the greatest part of the current will pass through the copper, on account of the greater conductivity of the metal. On the other hand, if the discharge from a condenser be sent through the system, the iron is seen to melt, and the copper remains intact, the iron having therefore carried the greater part of the current. The phenomenon of the discharge being oscillatory, and of very short period, the apparent conductivity of the iron wire has increased in a large proportion. The different results obtained by M. Maurain in comparing the effect of fusion produced by discharges or by continuous currents are, in the author's opinion, not very conclusive.

C. SEGUY—ON A CROOKES TUBE OF SPHERICAL FORM SHOWING THE REFLECTION OF CATHODE RAYS BY GLASS AND METAL.

(Comptes Rendus, Vol. 122, No. 3, p. 134.)

This tube consists of a hollow glass vessel exhausted to one-millionth of an atmosphere, and contains a star-shaped aluminium electrode, E. A second electrode, S, has the form of a small disc, D, placed near the side of the glass, parallel to the star. If this be connected to an induction coil giving a 10-cm. spark, disc B being connected to the negative pole, luminous phenomena are observed, which are evidence of the reflection of the cathode rays by glass and metal. The beam of cathode rays emitted by D strikes against the opposite boundary, D′; the dark shadow of the star is seen in the centre of the luminous region. These same rays, reflected on the glass at D_1, return to illuminate the surroundings of D, forming a second shadow of the star E, larger than the first.

The aluminium star then reflects a part of the beam D which results in a luminous projection of this star, inscribed in the centre of the shadow of this same star formed on the wall D. If the aluminium star be made cathode, the luminous phenomena are simplified, only in this case the star is seen projected on the opposite glass boundary, itself producing two full-size luminous images.

H. SWYNGEDAUW—DIFFERENCE IN THE ACTION OF ULTRA-VIOLET LIGHT ON STATIC AND DYNAMIC EXPLOSIVE POTENTIALS.

(Comptes Rendus, Vol. 122, No. 3, p. 131.)

Most of the physical conditions causing a variation in the decrease of the explosive potential of an exciter have been studied by various experimenters.

The author studies the influence of the method of charge of the exciter. The

author has previously published the law which governs this influence. The lowering of the explosive dynamic potential of an exciter illuminated by ultra-violet light is notably greater than the lowering of the static explosive potential. The lowering of the static explosive potential of the exciter is measured directly by means of an absolute electrometer, the charge being obtained from a Holz machine.

The lowering of the explosive dynamic potential is measured in the following manner:—The two ends of a coil receiving the discharge from a Leyden jar were connected with the two poles of an exciter. The potential difference of the exciter, which is 0 at the commencement of the discharge, passes in a very small fraction of a second to a given value, depending on the potential to which the condenser has been charged.

If the jar has been charged to 50 C.G.S. electrostatic units, the poles of the exciter are then raised to a potential of 52 electrostatic units. The experiments were carried out in the following manner:—A Leyden jar circuit, containing a coil with ends B_1 and B_2, is interrupted by a main exciter, I. The extremities B_1 and B_2 are in contact with the poles of an exciter, E, connected as a shunt. The main exciter is maintained as constant as possible. The maximum explosive distance between the poles of the shunt exciter is then arranged so that at each main spark at I a shunt spark is observed at E (1) when the exciter E is not illuminated; (2) when it is illuminated by the source of ultra-violet radiations employed.

The author defines the maximum distance in the same way as Mr. Lodge, viz., the "critical distance" of the shunt exciter. Experiment shows that if with a given discharge and exciter the critical distance is d when the exciter is not illuminated, it then becomes $d + \Delta$ when the exciter is illuminated by the ultra-violet radiations; Δ being an appreciable fraction of d. The lowering of explosive dynamic discharges can be deduced from the following propositions:—

1. The static and dynamic potentials of an exciter screened from ultra-violet radiations are equal to one another.
2. The explosive potential corresponding to the critical distance d of the exciter E which is not illuminated, is the maximum potential, V′, to which the discharge can raise the potential of the poles of the shunt exciter.
3. If no spark takes place in the shunt exciter, the law of the condenser discharge is not altered by a change in the physical conditions under which the exciter is working; the result of this proposition is that the explosive dynamic potential, $V\,(d + \Delta)\,e$, of the exciter E illuminated for the critical distance $(d + \Delta)$ cannot exceed the maximum potential V′, and, indeed, is generally shown to be much below it.

If $V\,(d + \Delta)\,e$ determines the static explosive potential of the illuminated exciter for the distance $d + \Delta$, the static decrease of the exciter E for the distance $d + \Delta$ will be

$$A = V\,(d + \Delta)\,n - V\,(d + \Delta)\,e.$$

The following are the results of a few experiments made with a condenser of 0·005 microfarad capacity discharging through a resistance of 1 ohm, a self-

induction of a few 1-10,000ths quadrant, the shunt exciter consisting of two brass balls 1·6 cm. diameter. The main exciter is formed of spheres 2 cm. diameter; its explosive potential is called V_1. The potentials are considered in C.G.S. units. The light from a 15-ampere arc lamp was concentrated by means of a quartz lens on the poles of E.

$$V_1 = 58;$$
$$d = 4\cdot5 \text{ mm.} \qquad V\,d\,n = 52;$$
$$d + \Delta = 5\cdot4 \text{ mm.} \qquad V\,(d + \Delta)\,n = 60 \quad \ldots \quad A' \geqq 8;$$
$$V\,(d + \Delta)\,e = 58 \quad \ldots \quad A = 2.$$

The experimental results interpreted in this manner clearly demonstrate the above propositions.

A. ANDREOLI—THE PROGRESS OF THE ELECTROLYSIS OF CHLORIDE SOLUTIONS.

(*L'Éclairage Électrique, Vol.* 6, *No.* 2, *p.* 81.)

It has been practically demonstrated that hypochlorites as produced by electrolysis are of little value, the reason being that when, say, 100 kilos. of chloride in solution are decomposed by electrolysis, nearly the whole is left undecomposed in the hypochlorite.

The solution can scarcely be used again, for, when it has been used for the purpose of bleaching paper pulp or fibres, it is so charged with organic substances that it would be necessary to employ some purifying process.

Hypochlorites will cease to be of any practical value unless some method is discovered for producing at least three grammes of chlorine per litre. But even this amount is very small, and it becomes advantageous to employ solutions of chloride of lime to be transformed into hypochlorite of magnesium, sodium, or zinc, and which can afterwards be diluted as required.

The failure of the production of hypochlorites led to investigations on chlorine, caustic soda, and carbonate of soda. Two things were found essential in the electrolytic process, viz., an insoluble anode and an indestructible diaphragm. Unfortunately, as soon as the latter is attacked, the output of chlorine and soda is reduced, and having to replace it, means stopping the work. This process was found impracticable on account of the small output of caustic soda.

The Greenwood process was then introduced in 1892, and this was not capable of producing more than 10 per cent. of caustic soda in solution. There existed too much undecomposed chlorine in the liquid to be evaporated, and the soda was not pure. This process was owned by the "Caustic Soda and Chlorine Syndicate," which has since ceased operations. The Richardson and Holland process was then introduced, and consisted in employing a non-porous diaphragm reaching to about 3 cm. from the bottom of the vat.

Notwithstanding the small aperture between the positive and negative vat, only 6 volts were necessary for the process. Although the production of hypochlorite was inevitable in a process of this sort, an output of 14 per cent. of caustic soda in solution was realised.

In other methods the output amounted to 7, 8, or 9 per cent.; but from a certain point the output decreased, and then, as in the case of hypochlorites, the process shows a loss, for the caustic soda becomes a better conductor than the chloride of soda, and absorbs the greatest part of the electrical energy. This has since been superseded by the Castner process, developed in the works of the Aluminium Company of Oldburn. The chloride produced has a purity of 95 to 97 per cent., and the caustic soda is free from all traces of hypochlorite or of chloride of soda.

In this process the mercury is not employed as cathode, but as the diaphragm, and its originality and effectiveness depend on this point. Two non-porous diaphragms divide the vat into three compartments, and stop at 1 cm. from the bottom, where the mercury is placed, thus forming a diaphragm of low resistance. The mercury is caused to pass alternatively into the positive and negative compartments by the automatic rocking of the vat. The mercury collects the sodium, and brings it to a central compartment containing water, at the surface of which caustic soda is formed.

J. PERRIN—NEW PROPERTIES OF CATHODE RAYS.

(*Comptes Rendus, Vol.* 121, *No.* 27, *p.* 1130.)

Two hypotheses have been established explaining the properties of cathode rays. Goldstein, Hertz, and Lenard advocate that this phenomenon is due, as in the case of light, to vibrations in the ether, or even that it is a form of light with a short wave-length. It can then be conceived that these rays have a rectilinear trajectory, excite phosphorescence, and have an effect on photographic plates.

Others, including Crookes and J. J. Thomson, believe that these rays consist of negatively charged matter and travel at a great rate. It then becomes easy to conceive their mechanical properties, as well as the manner in which they are affected by a magnetic field. The author has made a few experiments based on the latter hypothesis, of which the following is a *resumé* :—

His first experiment consisted in verifying the assumption that the cathode rays are negatively charged. The cathode rays were caused to pass into a Faraday cylinder, made of metal, and having an aperture at one end. A wire fixed to the other end is connected to an electroscope. This cylinder is enclosed within a second metallic cylinder, permanently connected to earth, and having a small aperture at each end. This is used for protecting the Faraday cylinder against all external influence. At a distance of 10 cm. in front of one of these apertures is placed an electrode, N, fused into the outer glass tube, which serves as cathode, the anode consisting of the protecting cylinder. A pencil of cathode rays will accordingly penetrate the Faraday cylinder, which invariably becomes negatively charged. The exhausted tube was arranged for placing between the poles of an electro-magnet, under which conditions the cathode rays were deviated : the rays no longer entered the Faraday tube, which was, under these conditions, found not to be charged. When the magnet was not excited the tube was found to be again charged. From this result it is inferred that the cathode rays are charged

negatively. It is possible to measure the quantity of electricity carried by these rays. The author has not completed his measurements, but he states that with one of the tubes, and with a single interruption of the primary coil, the Faraday tube was sufficiently charged to produce 300 volts in 600 C.G.S. units capacity.

Having verified that the cathode rays are negatively charged, the author endeavoured to localise the corresponding positive charges. He believes them to exist in the same region as that in which the cathode rays are formed, and to move in an opposite direction—that is to say, towards the cathode.

In order to verify this hypothesis, a hollow cylinder was used, containing a small aperture, through which a small portion of the attracted positive electricity was allowed to pass. The electricity could then charge the Faraday cylinder contained within the above protecting cylinder. The anode consisted of the same electrode as used in the above experiments. Under these conditions the Faraday cylinder was invariably charged with positive electricity, the charge being of the same order as the negative charges observed in the previous experiments. The object of further experiments was to ascertain whether this positive flux formed a second system of rays absolutely symmetrical to the first. For this purpose an analogous tube to the preceding one was used, but with the addition of a diaphragm placed within the tube opposite the aperture. The electrode N was used as cathode, the cathode rays passing without difficulty through the two apertures, and strongly repelling the leaves of the electroscope. When, however, the protecting cylinder is made cathode, the positive flux—which, according to the preceding experiment, passes through the aperture—does not deflect the gold leaves except at very low pressures. By substituting an electrometer for the electroscope, it is ascertained that the action of the positive flux exists only to a small degree, and increases with a decrease of pressure. In a series of experiments at a pressure of 20 m., it produced a P.D. of 10 volts in a capacity of 2,000 C.G.S. units, and with a pressure of 3 m. the capacity was charged to 60 volts. A magnet has the effect of entirely stopping the action.

In concluding, the author considers that these results are not easily reconciled with the theory which associates cathode rays with ultra-violet light. On the other hand, they conform with the theory which considers them as material radiation, and which can be summed up as follows:—In the neighbourhood of the cathode, the electrostatic field is sufficiently intense to dissociate into ions certain molecules of the remaining gas. The negative ions pass to the region where the potential increases, attain a considerable velocity, and form cathode rays; their electric charge, and, consequently, their mass, being easily measurable. The positive ions move in a contrary direction, forming a diffused brush. They are affected by a magnet, and cannot be considered as forming a true radiation.

H. LE CHATELIER—ON THE COMBUSTION OF ACETYLENE.

(*Comptes Rendus, Vol.* 121, *December, p.* 1144.)

The methods adopted for carrying out these experiments on acetylene were the same as those previously employed by M. Mallard and the author on other gases.

1. *Reactions of Combustion.*—It was found that mixtures of acetylene with air containing less than 7·74 per cent. per volume of air produce a yellow flame of small illuminating power, with the formation of carbonic acid and water. For proportions of gas included between 7·74 and 17·37 per cent. the flame is a pale blue with a pale yellow halo; the products of combustion are carbonic acid, carbonic oxide, steam, and hydrogen. For proportions of acetylene above 17·37 per cent., incomplete reactions take place, giving rise to the formation of carbonic oxide, hydrogen, free carbon, and also some unburnt acetylene. The precipitation of carbon in the form of lampblack is very marked with mixtures containing more than 20 per cent. The flame then becomes luminous, and of a red colour. There remains after the passage of the flame a black opaque cloud of precipitated carbon.

2. *Limits of Inflammability.*—Taken in an indefinite quantity, the only inflammable mixtures are those for which the proportion of combustible gas is contained between the following extreme limits:—

	With Oxygen. Per cent.	With Air. Per cent.
Lower limit of inflammability	2·8	2·8
Higher " "	93·0	65·0

When tubes are used the limits become closer together as the diameter decreases.

3. *Rate of Propagation of the Flame.*—The experiments were made with a tube 40 mm. diameter. The shape of the curve representing velocities is quite different to those of previously studied gases. The maximum velocity is obtained with a mixture containing an excess of combustible gas, with respect to the available oxygen. This result is similar to those obtained with other combustible gases.

4. *Temperature of Ignition.*—This is close upon 480°, which is much lower than that of other combustible gases, which is generally about 600°. The explosive mixtures of acetylene are very easily ignited by enclosing them in a glass tube and then heating for a few moments over a spirit lamp. The explosion takes place much before the glass softens.

5. *Temperature of Combustion.*—The temperature of combustion of mixtures of acetylene with air can be calculated from the specific heats deduced by M. Mallard and the author from their experiments on combustible gases. Acetylene, on account of its endothermic constitution, has a much higher temperature of combustion than other gases, of which the temperature of combustion is approximately 2,000°. When burnt with its volume of oxygen it would have a temperature of 4,000°, or 1,000° above that of the oxygen flame, the products of combustion consisting entirely of such reducing agents as carbonic oxide and hydrogen.

These properties will render acetylene very useful in laboratories for producing high temperatures with the blow-pipe, or using in ordinary burners for spectrum analysis.

E. ANDREOLI—INDIRECT ELECTROLYSIS.

(*L'Éclairage Électrique, Vol.* 6, *No.* 1, *p.* 42.)

An electrolytic vat is divided into three compartments, A, B, C, by two porous partitions; the anode and the cathode dipping respectively into the compartments A and C, containing either the same or different electrolytes, the centre

compartment, B, also containing some electrolyte. The decomposition of the electrolytes A and C takes place as though the centre one were not present, and the solution in the middle compartment is unaffected by electrolysis taking place in the two outer cells. If, however, into the solution of the centre compartment is dipped a metallic plate or plates, reactions immediately take place, which can only be attributed to indirect, or secondary, electrolysis.

In one of the author's experiments the two compartments A and C are filled with a solution of rock salt, and the centre compartment with a weak or concentrated solution of cyanide of gold,—the anode consisting of a plate of retort carbon, and the cathode of a plate of iron. Directly current is established. chlorine is produced at the anode, and soda at the cathode; but the solution of cyanide of gold is not altered by the passage of the ions. If metallic plates be dipped into the middle compartment they become coated with gold, and the cyanide solution is exhausted more or less quickly, depending on the strength of the current and on the number of plates; the solution being contaminated neither by chlorine nor soda. In a second experiment, the three compartments were filled with the same solution of cyanide of gold, the anode consisting of lead, the cathode of iron, metallic plates dipping into the middle compartment. At the end of seven days a sample was taken from the end compartments: it had exactly the same composition as at first, and no deposit of gold was observed on the cathode. No electrolytic action had, therefore, taken place in these compartments, although nearly 100 litres of solution of cyanide of gold had been exhausted during this period, in the centre compartment.

In another experiment, the author was able to transform bisulphite of sodium into hydrosulphite of sodium. The solution of bisulphite is placed in the centre compartment, and, as in the case of cyanide of gold, no effect takes place as long as any metallic plate dips into the electrolyte. As soon, however, as two plates are immersed at the ends of the centre compartment, electrolysis takes place, and the liquid rapidly acquires decolorising properties, which it previously did not possess; and the author states that under certain conditions this electrolytic process presents marked advantages over the ordinary process.

C. E. GUYE—TRANSMISSION OF POWER, CHEVRÈS-GENEVA.

(L'Éclairage Électrique, Vol. 6, No. 4, p. 147.)

In 1885 was started the water-power station of Geneva, designed by M. Turettini, and which utilises the force of the Rhone.

The Coulouvrenière station, built on the Rhone, contains at the present time 17 turbines of 300 H.P. each, the total power being employed for hydraulic supply in the town and surroundings. The turbines are used to drive pumps, and, in order to ensure a continuous supply, the system is connected with a reservoir of 12,000 cubic metres capacity, situated at a height of 140 metres above the lake. A large portion of this power is utilised for electrical purposes. The electric lighting is carried out by two distinct circuits. The older of the two supplies 15,000 100-volt lamps with continuous current. The machines are divided into four groups, each group consisting of two 220-H.P. Thury dynamos coupled to the same turbine

spindle. The second circuit, which was started in 1892, supplies the outskirts of the town, and receives current from two alternators at 2,500 volts and 54 frequency. The high-tension current is carried to the transformer sub-stations by two concentric cables more than 6 kilometres long. The low-tension 110-volt distribution is on the three-wire system, and supplies more than 6,000 lamps. The Coulouvrenière station also supplies power for electric traction.

The generators employed for this purpose are two continuous-current 500-volt dynamos, each of 240 H.P. Extensions are soon to be made to both the electric lighting and traction in Geneva. The only electric power transmission in Geneva is over a distance of 2·7 kilometres, supplying power to the Compagnie de l'Industrie Electrique at 1,200 volts.

The success of the Coulouvrenière station has led to the construction of a second hydraulic power station, which will be in operation in a few months. This station, at Chevrès, is situated about 6 kilometres in a straight line from the former station. It will contain 15 turbines, each of 800 to 1,200 H.P., and develop 12,000 to 15,000 H.P. during the season. The power will be transmitted to neighbouring towns at 2,400 volts on the two-phase system. This extension will relieve the Coulouvrenière station of part of its load, which will be kept as a reserve. The alternators are to be placed horizontally, and to be coupled direct to the turbine spindle. The exciting current is supplied by auxiliary turbines. The line from Chevrès to Geneva consists of four stranded conductors placed underground in concrete troughs filled with bitumen and gravel.

E. WIEDEMANN—ON A NEW KIND OF RAYS CONTAINED IN SPARKS PRODUCED IN ELECTRIC DISCHARGES.

(Beiblätter, Vol. 19, *No.* 10, *p.* 811.)

If different substances are subjected to the action of electric sparks at a distance of 2 to 4 cm., and afterwards heated, they are seen to phosphoresce. It was hitherto considered by Becquerel that these effects were excited by the ultra-violet rays. The author's experiments show that this is not so, and that the effects are caused by a new kind of rays which he calls "discharge rays," as their nature is at present uncertain. They appear to be similar to the cathode rays, but are not deviated by magnets. Similar rays also appear to exist in the positive light of a vacuum tube. The presence of these rays can be readily detected by allowing them to act at a distance of 2 cm. from the following substances: sulphate of calcium containing a trace of sulphate of manganese, carbonate of calcium containing a trace of carbonate of manganese, sulphate of sodium containing a small quantity of sulphate of manganese. A part of the substance should be covered with quartz or fluor spar. On heating there appears a bright thermo-luminescence on the uncovered part. Fluor spar is consequently not transparent to these new rays, and air, on the contrary, does not absorb them. The above action cannot, therefore, be due to ultra-violet rays, as, according to Schumann's experiments, the extremest ultra-violet light is entirely absorbed by air, whilst fluor spar extinguishes the light only from $\lambda = 100$ $\mu\mu$. The author is making further experiments on this subject.

ANON.—THE ZERENER ELECTRIC CASTING, WELDING, AND SOLDERING PROCESS.

(*Elektrotechnische Zeitschrift*, 1896, *No.* 4, *p.* 46.)

The four processes in use at the present time, evolved from the Elihu-Thomson process, are the Thomson, the Bernadoss-Stavianoff, Zerener, Laugrange-Hoho. The Zerener process was developed in 1889, since which time the inventor has made many investigations on the effect of a magnetic field on the electric arc, working especially with a horse-shoe magnet. The influence of the horse-shoe magnet on the arc is to blow it out in the form of a pointed flame.

With the apparatus employed for the above investigations the relative distances of magnet pole and arc could be readily altered. The influence of the relative positions of the two carbons was studied under all conditions. It was found that the arc has a natural tendency to point outwards when the carbons make an angle with one another. There is an advantage in placing them in this position for ease in soldering.

Electro-magnets are preferably used. On some of the hand tools regulating resistances are provided, the regulation of the instrument consisting chiefly in altering the strength of the magnet.

The carbons should be as hard as possible. The use of cored carbons, and carbons containing special materials, has received special attention, and the inventor proposes to employ different substances in the carbons for different requirements.

Self-regulating apparatus, of sizes varying from 35 to 250 amperes, have been supplied to several German firms, working off 65-volt circuits.

In the processes of welding and casting, protecting shields fitted with small windows are used. Special spectacles are worn by the operators.

The minimum power required for a self-soldering apparatus is 3 amperes, 40 volts.

ANON.—THE ELECTRIC STREET TRAMWAYS IN AIX-LA-CHAPELLE AND THE FIRST EXTENSION OF THE MUNICIPAL WORKS.

(*Elektrotechnishe Zeitschrift*, 1896, *No.* 1, *p.* 4.)

The above tramway commenced operations in August, 1895, and consists of 26 kilometres of rails, 34 motor cars. An extension of 12 kilometres and six additional motor cars is proposed. The Schuckert system was adopted. The velocity of the cars in the streets is, on an average, 15 kilometres per hour, which is maintained even up gradients. The rails used in the town are 17 cm. high, and weigh 36 kilogrammes per metre run; those on the macadamised roads are 10 cm. high, and 18 kilogrammes per metre run.

Power was obtained from the municipal electrical works, which was specially designed to cope with sudden and varying loads. As with the above large number of motor cars there exists a fair uniformity in the load, compound engines were employed, supplied by Kuhn, of Stuttgart. The maximum variation of speed was guaranteed not to exceed $1\frac{1}{4}$ to $1\frac{1}{2}$ per cent.

The consumption of steam at the normal initial pressure of 10 atmospheres amounts to 8 kilogrammes per I.H.P. at the normal load of 180 H.P., and 8·2

kilogrammes per I.H.P. at the maximum load of 230 H.P., the efficiency of the engine being 85 per cent.

A motor transformer of 150 kilowatts and 220 to 550 volts is kept as a reserve, and is equal in output to one of the generators.

The boilers work at a pressure of 12 atmospheres, and have a capacity of 2,600 kilogrammes of dry steam.

The dynamos are shunt-wound, and are direct-coupled to the engines. The combined efficiency is 92 per cent. The output of the dynamos is measured on Schuckert meters. Each feeder is provided with an automatic cut-out and lightning protector. The working conductor, consisting of a copper wire 7 mm. diameter, is fed by insulated feeders radiating from the station; and the rails, together with a bare copper wire laid along the tram, form the return conductor.

The working conductor is divided into a number of insulated sections, corresponding to the number of feeders, and these sections are further subdivided. Switches are provided between the sections to allow of any faulty one being cut out. Every section is provided with a lightning protector. The working conductor is supported by means of steel wires fixed to poles or brackets. Arrangements are provided at distances of 400 to 500 metres for straining the individual sections. The drop of pressure over the system does not amount to more than 10 per cent.

The cars are of the Schuckert type. The lower frame carrying the motors is suitably shaped to clear any obstacle from the track.

The weight of the complete car is 5,500 kilogrammes. As in Aix the gradients amount in some places to 90 in 1,000, the cars are fitted with two motors of 15 to 20 H.P., each motor driving one axle by means of single-reduction gearing. The teeth are cut with great care in order to minimise noise. The motor wheel consists of a compressed material. The gearing is enclosed in an oil box.

The motors are of the ironclad type, and are supported on springs. They are specially designed to be capable of withstanding four times their normal load.

The starting and stopping and regulation of speed take place by means of a single handle, regulation being effected by altering the field strength of the motors. When going down hill the motors run as dynamos loaded up on resistances, and thus act as brakes.

The trolley bar consists of a steel tube so arranged that it can be completely lowered to allow the car to pass through tunnels. The springs are so designed as to be always in the same degree of tension. Two conductors are fixed to the trolley—one connected to earth through a lightning protector, and the other through a self-induction coil to the apparatus on the car.

Arrangements are made for working one motor only if required.

V. VON LANG—OBSERVATIONS ON THE CHANGE PRODUCED BY ELECTRIC RAYS ON THE CONTACT RESISTANCE OF TWO CONDUCTORS.

(*Wiedemann's Annalen, Vol.* 57, *Part* 1, *p.* 34.)

It was discovered by Branly (*C. R.*, p. 785, 1890) that electric rays have the property of lessening the resistance of metallic filings contained in glass tubes, and

that a slight shaking of the tubes re-establishes their original resistance. Lodge showed that this effect is very marked when only a single contact is employed between two metals. The author employed the following apparatus for the purpose of experimenting with different metals, including carbon:—To the end of a lever is fixed a sleeve holding the metallic rod, which rests on a metallic plane, these consisting of the metals being dealt with. The arrangement is provided with screw adjustment, to allow the contact to be adjusted. Across the contact is connected a dry cell and 7,000-ohm mirror galvanometer.

To carry out the observations the two conductors were brought together by such an amount that the deflection of the galvanometer was scarcely perceptible.

The electric rays were produced by a Clark electric gas lighter working on the same principle as the Toepler influence machine. These were produced at a distance of about $\frac{3}{4}$ m. from the point of contact, and their effect was to deflect the galvanometer, which immediately returned to its original position; the contact had then lost its sensitiveness, and had to be reset. The author in his researches on carbon employed a rod 8 mm. diameter, with its end resting on a carbon plate; these having previously been boiled in aqua regia to free them of metallic impurities. It was found that the spot deflected and remained steady after the action of the spark, and returned to its original position after a gentle shaking of the apparatus. The contact had not, however, lost its sensitiveness. The same result is obtained with Branly's tubes containing metallic filings. The author finds that this property is not only characteristic of carbon, but also of other metals, such as Zn–Zn, Al–Al, Al–Zn, so long as shaking is avoided. The spot was, for instance, deflected in the last case by the discharge of the electrophorus from 20·8 degrees to 41 degrees, which represents a variation in the resistance from ∞ to 380 megohms. The spot remains in the deviated position, and only returns when the cover is gently replaced on the electrophorus.

J. ELSTER and H. GEITEL—ON THE SUPPOSED DISPERSION OF POSITIVE ELECTRICITY BY LIGHT.

(Wiedemann's Annalen, Vol. 57, Part 1, p. 24.)

Experiments show that, whilst the illuminating of a negatively charged surface has the effect, under suitable conditions of light, &c., of producing a rapid dispersion of the charge, the effect in the case of a positive charge (if any) is comparatively much smaller. Messrs. Stoletow and Righi had, as well as the authors, failed to observe any dispersion of positive electricity due to the action of light. The authors refer to Mr. Branly's experiments on the acceleration of the dispersion of positive electricity due to the ultra-violet light, and on repeating these experiments were unable to confirm them.

The method employed by Mr. Branly consisted in observing the deflection of the leaves of a gold-leaf electroscope to which the illuminated surface was connected. This method necessitates perfect insulation in order to prevent leakage.

The method employed by the authors, as well as by Mr. Righi, was specially adapted for measuring small effects, and consisted in producing ultra-violet light by the spark discharge of a condenser connected to the poles of an induction coil.

The discharge took place between two aluminium wires 2 mm. apart. This apparatus was separated from the observing apparatus by means of an iron screen connected to earth and fitted with a quartz lens focused for the sparks; the electrical effects of the induction coil being thus excluded. At a distance of 25 cm. from the iron screen was placed an iron wire gauge with 1-mm. mesh, and parallel to this, at a distance of 2 to 4 mm., an insulated plate of the material under examination. To this plate was connected a quadrant galvanometer, and the wire gauze was charged from a 525-volt battery. It was observed that with a positive charge of the wire net the plate was negatively charged on its surface, and it was consequently expected that under the action of ultra-violet light a discharge of electricity from it to the net might take place. An amalgamated plate of zinc was used, covered with a thin layer of paraffin or tallow, and also a wooden plate covered with tallow. According to Mr. Branly, such surfaces covered with tallow showed a greater dispersion of positive than negative electricity under the action of light.

The reading of the electrometer was taken after one minute's positive and negative charge of the wire net, both in the light and in the dark. A table is given showing the change of the potential of the plate under these conditions, measured in volts. Only in two cases is the weak transference of electricity observed to be stronger in the light than in the dark—viz., with a negatively charged net, in the case of the amalgamated plate, and a positively charged net in the case of the paraffined zinc.

The observations show that waxed and paraffined surfaces are not photo-electrically sensitive, and in no case has the dispersion with a positive charge been found greater than with a negative charge.

The authors found a considerable advantage in employing an aluminium-leaf electroscope, as this is not too sensitive.

The results of the experiments led the authors to believe that an unobserved error might have led to Mr. Branly's results.

In order to verify this, the authors worked with the same apparatus. In this case the sparks were produced in an iron box connected to earth and fitted with a quartz lens, and opposite the latter was placed the insulated and electrified plate connected to the electrometer. In this case no wire net was used. So long as the plate was placed about 50 cm. from the quartz lens it was observed that an increase in the electrical dispersions produced by light, existed only with negative charges. If, however, the plate was moved to a few cm. from the lens, and its surface paraffined, it was found that the rate of dispersion was apparently greater with a positive charge than with a negative charge. But in this case the positive charge of the plate induced a negative charge in the iron box, and the action of the ultra-violet light reflected from the waxed surface might produce a transference of negative electricity to the plate, which would explain the above effect, and account for Mr. Branly's observations. The authors therefore consider that it has not yet been confirmed that ultra-violet light has the effect of increasing the dispersion of electricity from a positively charged surface.

The authors have mentioned previously that with exhausted gas globes containing electrodes of platinum and of an alkali-metal the photo-electric current

is affected if the alkali-metal surface forms the positive pole. It was considered that the platinum electrode was the seat of the light. The authors have endeavoured to localise the light. It was found that with the cell connected as above the strength of current is much too small, even in strong light, to produce any appreciable effect, even on the very sensitive galvanometer employed to measure photo-electric currents. The same methods were, therefore, employed as in the experiments on ultra-violet light—*i.e.*, the alkali-metal surface was connected with the positive pole of the battery, and the platinum electrode with the quadrant electrometer. The passage of electricity through the cell was evidenced by the constant increase in the deviation of the electrometer needle. Difficulties were experienced due to the glass cell becoming coated with a film of the alkali-metal, which allowed the escape of negative electricity under the action of light. This was overcome by making the wall of the cell of the same potential as the alkali-metal anode, by coating the outside of the former with a layer of precipitated silver, leaving a small aperture for the passage of the cathode, and another for the admission of light. Under these conditions the photo-electric discharge was observed with great clearness.

These experiments with ordinary light on alkali-metal surfaces in vacuo lead to the same conclusion as those with ultra-violet light in air, viz., that the photo-electric effect is limited to the cathode.

K. WESENDONCK—ON THE DISCHARGE FROM POINTS PRODUCED BY VERY HIGH FREQUENCY ALTERNATING CURRENTS.

(*Beiblätter*, *Vol.* 19, *No.* 14, *p.* 922.)

Messrs. Harvey and Hird [*Phil. Mag.* (5), xxxvi., p. 45, &c., 1893] and M. Himstedt (*Wied. Ann.*, lii., 1894) have found that high-tension currents of high frequency, or so-called Tesla currents, have the effect of producing a discharge of electricity from points which are positively charged.

In order to prove this effect, M. Doule produced rapid oscillations in two parallel conductors about 4 metres long by means of a Blondlot exciter, and the sign of the discharge from a needle point was measured. The discharge through wide limits of excitation was found to be positive. The author's experiments show that this discharge phenomenon is due to the high frequency and not to the high pressure.

M. TOPLER—ON THE ELECTRIC CONDENSER OSCILLATIONS PRODUCED WITH MULTIPLE-PLATE INFLUENCE MACHINES, AND THEIR USE IN THE SO-CALLED TESLA EXPERIMENTS.

(*Beiblätter*, *Vol.* 19, *No.* 10, *p.* 797.)

This paper, read at Vienna, first mentions a new method of showing the Hertzian experiments objectively. On the secondary conductor, consisting of a plain, straight resonance rod, is fixed a ballistic electroscope constructed by the author, the deflection of which is measured by projection.

The influence machine produces two distinct kinds of sparks, and the experiments are divided into two sections, according to whether the condenser oscillations are transformed up or down. From the former is obtained a series of phenomena which have hitherto not been observed with electrostatic appliances. By the latter method almost all the Tesla experiments can be made. It was found that iron cores essentially reduce the voltaic induction of the high-frequency currents whilst cores of copper have hardly any effect at all.

W. BEZOLD — ON THE FORMATION OF THUNDERSTORMS AND THE UNSTABLE EQUILIBRIUM OF THE ATMOSPHERE.

(*Beiblätter, Vol.* 19, *No.* 10, *p.* 812.)

Peculiar to all thunderstorms is the presence of a strong vertical current of air. The electrical phenomena are probably only of a secondary nature. The rising air current no doubt tends to prevent the descent of large quantities of water existing in the form of clouds. In high altitudes thunderstorms are always accompanied by hail. The above current of air is no doubt produced by an alteration in the unstable equilibrium of the atmosphere.

The author shows how unstable conditions are produced in the atmosphere by the overheating and cooling of the air. The different causes and forms of unstable atmospheric equilibrum cannot at present be separated from one another, on account of the abscence of sufficient observations.

L. LEBIEZ — A NEW INFLUENCE MACHINE.

(*Beiblätter, Vol.* 19, *No.* 10, *p.* 797.)

The theory of this machine is similar to that of Lord Kelvin's replenisher. The machine consists of a stationary disc of glass on the outside of which are fixed two sectors of tinfoil. At a small distance from this disc is fixed a thin movable disc of ebonite on which are pasted a number of radial sectors.

In front of the movable disc is placed an ebonite rod carrying two ball-shaped exciters, and to which are fixed two U-shaped conductors, which surround both discs, and also end in balls which are respectively connected to the tinfoil layers of the fixed stationary disc.

The exciting balls carry small brushes of Dutch metal making contact with the sectors of the movable disc. There is fixed on the axle a non-insulated movable neutral conductor carrying brushes at its ends.

The machine cannot change the sign of the charge, and is specially adapted for producing long sparks.

F. OTTEL — ON THE ELECTROLYSIS OF H Cl WITHOUT A MEMBRANE.

(*Beiblätter, Vol.* 19, *No.* 11, *p.* 910.)

If H Cl be electrolysed without a membrane, chlorine gas is liberated, and the production is considerably below the calculated value on account of the chlorine being dissolved. The best results are obtained by using a mixture of

a concentrated brine solution and sulphuric acid. With a surplus of sulphuric acid there escapes a fair quantity of oxygen; this, however, almost ceases with an excess of Na Cl, whilst hydric hypochlorite of sodium is formed. With an increase in the electrolysis, the pressure rises. At 600 amperes the pressure commences at 1·8 volts, rises gradually to 2·8, and then rapidly to 3·7. The latter rising increase corresponds to the point where the liquid reacts only very weakly.

A. ABT—THE MAGNETIC PROPERTIES OF PYRROTHINE.

(*Wiedemann's Annalen*, *Vol.* 57, 1896, *p.* 135.)

Pyrrothine is a sulphate of iron, the composition of which is represented by the formula $Fe_7\ S_8$. This mineral has long been known to possess magnetic properties of which the intensity is comparable to that of magnetite. Besides its natural magnetism, pyrrothine is capable of being artificially magnetised, and of retaining a large portion of the magnetism thus imparted to it.

The author has compared pyrrothine to magnetite by studying different samples by the Gauss method. The following are a few of the results obtained:—The coefficient of maximum magnetisation of pyrrothine may exceed that of magnetite $\left(\frac{P}{M} = 1{\cdot}8862\right)$; as with all other strongly magnetic bodies, the magnetism at first grows more rapidly, and then more slowly, than the magnetising force. This increase is, however, slower in pyrrothine than in magnetite. This comparison has been made on samples possessing their natural shape. By comparing artificially cut prisms (10 cm. × 1·4 × 1·4), it is found that pyrrothine is far less magnetic than magnetite; the ratio of the maximum magnetisation being then $\frac{P}{M} = 2{\cdot}54$. Pyrrothine possesses a considerable coercive force, which is greater than that of magnetite.

J. ELSTER and H. GEITEL—ELECTRO-OPTIC EXPERIMENTS.

(*Wiedemann's Annalen*, *Vol.* 55, *p.* 684.)

When a beam of light is directed on to a cathode placed in a rarefied gas there is produced a photo-electric current, and this current is a maximum when the plane of polarisation is perpendicular to the plane of incidence, and minimum when the two planes are parallel. The authors have endeavoured to ascertain according to what law the photo-electric current varied with the direction of the plane of polarisation between these two extreme limits.

As it is very difficult to practically obtain a polarised ultra-violet beam, they used as cathode a liquid alloy of potassium and of sodium which is sensitive even to the visible radiations of the spectrum.

This alloy half fills a glass bulb about 50 mm. diameter. It would have been advantageous to employ a recipient closed by a mirror with parallel faces; a cement could not, however, be found which would not alter during the conditions of the experiment. However, vitreous phosphoric acid, powdered with

calcined oxide of zinc and washed, then covered with a mixture of wax and black rosin, gave fairly good results, and allowed several experiments to be made. The beam of light was supplied by an oxy-hydrogen zirconium lamp, and was limited by a slit. Measurements were made on the incident and reflected ray to ascertain that the beam of light fell exactly on the centre of the alloy.

The anode was placed about 10 mm. above the cathode. The angle of incidence was measured by an apparatus analogous to that employed to determine the height of the sun. Immediately in front of the recipient was placed a Nicol prism, and the slit regulated to such a size that during the rotation of the prism the beam always entirely traversed it.

When the polarised beam fell on the cathode with a different incidence to that of the normal incidence, then one observed during a complete rotation of the prism two maxima and two minima of the photo-electric current—the maxima when the principal section of the prism was parallel to the plane of incidence, the minima in the two positions at 90° to the above. By measuring the angle beginning from one of these maximum positions, the intensity of the photo-electric current is

$$J = A \cos^2 \alpha + B \sin^2 \alpha \quad \ldots \quad \ldots \quad \ldots \quad (1)$$

The positions of maxima and minima are more easily determined by turning the prism through 45°. Starting from these positions, and verifying, $J_{45^\circ} = \frac{A + B}{2}$; the prism being slightly displaced until the verification is made exactly.

The equation (1) gives directly $A - B = \frac{J - B}{\text{Cos}^2 \alpha}$, which enables the above law to be verified.

This law may be interpreted by admitting that the intensity of the photo-electric current is proportional to the luminous intensity, but having a coefficient of proportionality which differs according to whether the plane of polarisation, of the light is perpendicular or parallel to the plane of incidence.

The ratio $A : B$ depends on the incidence, A and B being very small for the normal incidence. A increases rapidly with the angle of incidence, is maximum towards 60°, and then decreases. B, on the contrary, diminishes, and appears to bend towards 0. On nearing the horizontal incidence, between 60° and 70°, $A = 50\,B$, approximately.

When the cathode consists of solid alkaline metal the surface is always rough and irregular, and then the photo-electric current is always independent of the angle of incidence of the light. In air, and with any metallic poles, the effect due to ultra-violet light increases also with the angle of incidence; but this variation is less sensitive than the variation observed in vacuo with alkali-metal electrodes.

CLASSIFIED LIST OF ARTICLES

RELATING TO

ELECTRICITY AND MAGNETISM

Appearing in some of the principal Technical Journals during the Month of FEBRUARY, 1896.

S. denotes a series of articles. I. denotes fully illustrated.

ELECTRIC LIGHTING AND POWER.

J. Reyval—"La Secteur de la Rine Gauche." Electricity Supply in Paris.—*Ecl. El.*, vol. 6, No. 5, p. 194 (I.).

D. Hurmuzescu—A High-Potential Laboratory Dynamo.—*Ibid.*, p. 211 (I.).

A. Charpentier—Gas and Electricity Concessions.—*Ibid.*, p. 235 (S.).

Anon.—The Control of Electric Installations with regard to Safety.—*Ecl. El.*, vol. 6, No. 6, p. 271.

G. Richard—Arc Lamps.—*Ibid.*, No. 7, p. 318 (I.).

S. Hanappe—Experiments on Transmissions.—*Ecl. El.*, vol. 6. No. 8, p. 352 (I.).

Anon.—The Triphase-Current Tramway of Lugano.—*Ibid.*, p. 365.

Anon.—Electric Installation in Zurich.—*E. T. Z.*, vol. 17, No. 6, p. 80 (I.).

Anon.—The Question of Standards for Glow Lamps.—*Ibid.*, No. 7, p. 109.

Anon.—The Glow-Lamp Question.—*Ibid.*, No. 8, p. 122.

Dr. H. Haas—The most Favourable Distance for placing Transformers apart.—*E. T. Z.*, vol. 17, No. 9, p. 130 (I.).

G. Meyer—A Method of Producing Thermo-electric Currents.—*Beibl.*, 1896, No. 2, vol. 20, p. 141.

DYNAMO AND MOTOR DESIGN.

Chas. Steinmetz—A Universal Alternating-Current Transformer.—*E. T. Z.*, vol. 17, No. 6, p. 78 (I.).

Professor E. Arnold—Notes on the Armature Winding of Continuous-Current Machines.—*Ibid.*, p. 82, No. 7, p. 104.

Dr. H. Behn-Eschenburg—Formulæ for Testing and Designing Three-Phase Motors.—*E. T. Z.*, vol. 17, No. 6, p. 83 (S. I.).

TRACTION.

A. Lavezzari—Electric Tramway from the Place Cadet to the Porte Montmartre in Paris.—*Ecl. El.*, vol. 6, No. 5, p. 226 (I.).

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L. Houllevigne—The Influence of Magnetism on Thermo-electric Properties.—*Jour. de Phys.*, vol. 5, February, 1896, p. 53 (I.).

M. Maurain—On the Energy dissipated in Magnetisation.—*C. R.*, No. 5, February, 1896, p. 228.

E. T. JONES—Magnetic Lifting Power.—*Wied. Ann.*, vol. 57, No. 2, 1896, p. 258.

H. NAGAKA—The External Effect of Uniformly Shaped Magnetic Ellipsoids of Revolution.—*Ibid.*, p. 275.

R. REIFF—New Explanation of the Magnetic Rotation of the Plane of Polarisation.—*Ibid.*, p. 281.

INSTRUMENTS AND MEASUREMENTS.

C. LIMB—Direct Measurement of Electro-motive Forces in Absolute Electromagnetic Units.—*Jour. de Phys.*, vol. 5, February, 1896, p. 61 (I.).

J. MACCRAE—On the Measurement of High Temperatures by means of Thermo-electric Elements, and on the Point of Fusion of a few Inorganic Salts.—*Ibid.*, p. 90.

J. E. MOORE—A Continuous- and Alternating-Current Magnetic Curve Tracer.—*Phil. Mag.*, No. 249, p. 106 (I.).

G. PELLISSIER—Incandescent Lamp Tests.—*Ecl. El.*, vol. 6, No. 6, p. 250.

H. ZIELINSKI—Influence of Temperature and the Duration of Electrification on the Insulating Properties of Gutta-Percha.—*E. T. Z.*, vol. 17, No. 6, p. 20 (S. I.).

F. KRÜGER—On Diaphragm Resistance.—*Beibl.*, 1896, No. 2, vol. 20, p. 140.

W. NERNST—On a Method of Determining Dielectric Constants.—*Wied. Ann.*, vol. 57, No. 2, 1896, p. 209.

J. E. SMALE—On an Alteration in the Electrometric Method for Determining Dielectric Constants.—*Ibid.*, p. 215 (I.).

TH. DES CONDRES—Measurement of the Electro-motive Power of Colley's Gravitation Elements.—*Ibid.*, p. 232 (I.).

W. WIEN—An Apparatus for Varying Self-Induction.—*Ibid.*, p. 249 (I.).

A. J. COLE—On the Refractive Exponents, and the Reflective Power of Water and Alcohol to Electric Rays.—*Ibid.*, p. 290.

TELEGRAPHY AND TELEPHONY.

Dr. WIETLISBACH—The Utility of Telephonic Translators.—*Jour. de Tel.*, vol. 20, No. 2, p. 25 (S.).

M. E. BAUDET—Multiple Telegraphy—*Ibid.*, p. 28, (S. I.).

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ANON.—Postal and Telegraphic Statistics in Italy for the Financial Year 1893-94.—*Ibid.*, p. 34.

ANON.—Telegraphy and Telephony in 1894 in the Island of Cuba.—*Ibid.*, p. 39.

ANON.—The Carbonelle Microphone on Belgian Circuits.—*Ecl. El.*, vol. 6, No. 5, p. 220 (I.).

DE B.—Optical Telegraphy, giving Secrecy to Dispatches.—*Ibid.*, No. 6, p. 255 (I.).

J. ANIZAN—On Telephony and Telegraphy.—*Ecl. El.*, vol. 6, No. 9, p. 385 (I.).

Dr. V. WIETLISBACH—The Horizontal Multiple Plug Board.—*E. T. Z.*, vol. 17, No. 6, p. 89.

ANON.—Switches for Single-Circuit Telephones.—*Ibid.*, No. 8, p. 120.

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R. W. Wood—On the Dissociation Degree of some Electrolytes at 0°.—*Phil. Mag.*, No. 249, p. 117 (I.).

— Epstein—Some Observations on Dry Cells.—*Beibl.*, 1896, No. 2, vol. 20, p. 140.

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J. L. R. Morgan—The Estimation of Cyanogen by Electrometric Methods.—*Ibid.*, p. 145.

F. Roever—On the Electric Endosmose of Tannic Acid Solution through Hides. —*Wied. Ann.*, vol. 57, No. 2, 1896, p. 397.

STATIC ELECTRICITY.

Gustave Le Bon—Invisible Light Photography.—*C. R.*, No. 5, February, 1896, p. 233.

L. Benoist and D. Hurmuzescu—New Properties of the *x* Rays.—*Ibid.*, p. 235; *Ecl. El.*, vol. 6, No. 7, p. 308.

Albert Nodon—Experiments on Röntgen Rays.—*Ibid.*, p. 237; *Ecl. El.*, vol. 6, No. 7, p. 309.

M. V. Chabaud—Transparence of Metals to the *x* Rays.—*Ibid.*, p. 237; *Ecl. El.*, vol. 6, No. 7, p. 310.

Albert Londe—Application to M. Röntgen's Method.—*C. R.*, No. 6, February, 1896, p. 311.

M. R. Swyngedaned—On the Lowering of Static and Dynamic Explosive Potentials by *x* Rays.—*C. R.*, No. 7, February, 1896, p. 374.

M. A. Righi—Electric Phenomena produced by Röntgen's Rays.—*Ibid.*, p. 376; *Ecl. El.*, vol. 6, No. 9, p. 390.

J. J. Borgman and A. L. Gerchun—Action of Röntgen Rays on the Electrostatic Charges and the Explosive Distance.—*Ibid.*, p. 378.

M. de Heen—An Experiment showing that the *x* Rays emanate from the Anode.—*C. R.*, No. 7, February, 1896, p. 383.

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C. Raveau—Röntgen Rays and Ultra-Violet Rays.—*Ibid.*, p. 249.

J. Blondin—Röntgen Rays.—*Ecl. El.*, vol. 6, No. 7, p. 289 (I.).

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P. Drude—On the Conception of Dielectric Resistance.—*Wied. Ann.*, vol. 57, No. 2, 1896, p. 223.

ATMOSPHERIC ELECTRICITY.

Professor A. W. RÜCKER—On the Existence of Vertical Earth-Air Electric Currents in the United Kingdom.—*Phil. Mag.*, No. 249, p. 99.

Dr. C. HESS—Poplar Trees as Lightning Conductors.—*E. T. Z.*, vol. 17, No. 9, p. 136.

THEORY.

F. GUILBERT—Alternating Currents and Complex Quantities.—*Ecl. El.*, vol. 6, No. 5, p. 217 (I.).

F. GUILBERT—On the Law of Hysteresis.—*Ecl. El.*, vol. 6, No. 8, p. 337, No. 9, p. 390 (S. I.).

A. CORNU—On Forces at a Distance, and Oscillations.—*Ibid.*, p. 343.

VARIOUS.

EDOUARD BRANLY—The Resistance of Thin Metallic Films.—*C. R.*, No. 5, February, 1896, p. 230.

M. G. H. NIEWENGLOWSKI—Observations on the Recent Note by M. G. Le Bon on Invisible Light.—*Ibid.*, p. 232.

M. G. MOREAU—On the Photographing of Metallic Objects through Opaque Bodies by means of the Brush Discharge from an Induction Coil without a Crookes Tube.—*C. R.*, No. 5, February, 1896, p. 238; *Ecl. El.*, vol. 6, No. 7, p. 310.

AUG. CHARPENTIER—On Negative Reaction and the Centre of the Retina.—*Ibid.*, p. 246.

D'ARSONVAL and CHARRIN—The Action of High-Frequency Alternating Currents on Bacteriological Toxines.—*C. R.*, No. 6, February, 1896, p. 280 (I.).

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M. MESLAUS—Influence of the Chemical Nature of Bodies on their Transparence to Röntgen Rays.—*Ibid.*, p. 309.

CHARLES HENRY—Increase in the Photographic Efficiency of Röntgen Rays by the Use of Phosphorescent Sulphate of Zinc.—*Ibid.*, p. 312.

CH. V. ZENGER—Photographic Results obtained by means of *x* Rays.—*Ibid.*, p. 315.

GOSSART and CHEVALLIER—On a Mechanical Action emanating from Crookes Tubes, analagous to the Photogenic Action discovered by Röntgen.—*Ibid.*, p. 315.

M. E. BOUTY—On Sensitive Flames.—*C. R.*, No. 7, February, 1896, p. 372.

AUGUSTE and LOUIS LUMIÈRE—Photographic Researches on Röntgen Rays.—*Ibid.*, p. 382.

A. IMBERT and H. BERTIN-SANS—Photographs obtained with Röntgen Rays.—*Ibid.*, p. 384.

M. G. H. NIEWENGLOWSKI—On the Properties possessed by Radiations emitted by Phosphorescent Bodies, of passing through certain Bodies opaque to Solar Light, and on the Experiments of M. G. Le Bon on Invisible Light.—*Ibid.*, p. 385.

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A. Briançon—Photographic Results obtained in the Dark.—*C. R.*, No. 7, February, 1896, p. 390.

H. Becquerel—On the Radiations emitted by Phosphorescence.—*C. R.*, No. 8, February, 1896, p. 420.

Ch. V. Zenger—On the Production of Röntgen Silhouettes.—*Ibid.*, p. 456.

Abel Bugnet and Albert Gascard—The Action of *x* Rays on the Diamond.—*Ibid.*, p. 456.

Darien and De Rochas—The Cause of Invisibility of Röntgen Rays.—*Ibid.*, p. 458.

M. Piltchikof—The Emission of Röntgen Rays from a Tube containing a Fluorescent Substance.—*Ibid.*, p. 461.

G. Le Bon—On a few Properties of Invisible Light.—*Ibid.*, p. 462.

Auguste and Louis Lumière—On Photography through Opaque Bodies.—*Ibid.*, p. 463.

M. Chesneau—On the Temperature of Sparks produced by Uranium.—*Ibid.*, p. 471.

J. Perrin—Some Properties of the Röntgen Rays.—*Ecl. El.*, vol. 6, No. 6, p. 246.

Gustave Le Bon—On Invisible Light.—*Ibid.*, p. 247.

Lannelongue, Barthelemy, and Oudin—The Use of Photographs taken by *x* Rays in Human Pathology.—*Ibid.*, p. 249.

A. Righi—On the Elongation of an Electric Spark produced by the Motion of the Electrodes.—*Ecl. El.*, vol. 6, No. 6, p. 262.

Ph. Delahaye—Researches on Useful Materials in the Manufacture of Incandescent Lamps.—*Ecl. El.*, vol. 6, No. 6, p. 273.

Hermann Lemp—The Electric Annealing of Ship Armour Plating.—*Ibid.*, p. 274 (I.).

G. Le Bon—Invisible Light Photography.—*Ecl. El.*, vol. 6, No. 7, p. 307.

A. Righi—New Experiments on the Globular Spark.—*Ibid.*, No. 8, p. 362.

Professor Bergonie (Paper read at the Bordeaux Congress)—Contraction provoked Electrically resembling Voluntary Contraction.—*Ibid.*, No. 9, p. 397.

Dr G. Darin—On Death by Electricity.—*Ibid.*, p. 398.

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Anon.—Siemens & Halske on the Production of Röntgen Rays.—*E. T. Z.*, vol. 17, No. 7, p. 105.

Von K. Streckler—The Spreading of Strong Electric Currents over the Surface of the Earth.—*Ibid.*, p. 106 (I.).

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A. Lebret—Alteration of the Hall Effect with Temperature (and other Articles on the Hall Effect).—*Beibl.*, 1896, No. 2, vol. 20, p. 147.

F. Vogel—On the Mutual Influence of Electric Conductors, especially those carrying Weak Currents.—*Ibid.*, p. 154.

W. Von Bezold—On the Isanormal Lines of Terrestial Magnetic Potentials.—*Ibid.*, p. 158.

JOURNAL

OF THE

Institution of Electrical Engineers,

Founded 1871. *Incorporated* 1883.

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The Two Hundred and Eighty-sixth Ordinary General Meeting of the Institution was held at the Institution of Civil Engineers, 25, Great George Street, Westminster, on Thursday evening, March 12th, 1896—Dr. JOHN HOPKINSON, F.R.S., President, in the Chair.

The minutes of the Ordinary General Meeting held on 27th February, 1896, were read and approved.

The names of new candidates for election into the Institution were announced and ordered to be suspended.

The following transfers were announced as having been approved by the Council:—

From the class of Associates to that of Members—

Juan Abella. | John William Chisholm.

From the class of Students to that of Associates—

A. E. Bennett. | Simon L. F. McLauchlan.
Albert W. Makovski.

Mr. George Driver and Mr. T. A. Rose were appointed scrutineers of the ballot.

The President: I will now ask Mr. Addenbrooke to complete his paper by any further remarks he may desire to make in reference to the various forms of high-voltage lamps exhibited this evening.

Mr. Addenbrooke.

Mr. Addenbrooke: There is very little, I think, which I can add to what I have already said. We have here now lamps exhibited by four different firms, and, so far as they want any explanation, I think that those who are exhibiting them would be the fittest persons to give those explanations. I might suggest that perhaps it would be better for the lamp-makers to speak first, and then we can go on to the consideration of the use of such lamps of central station practice afterwards.

The President: I see Mr. Swan here, and perhaps he will open the discussion.

Mr. Swan.

Mr. J. W. Swan: Mr. Addenbrooke's paper raises the question whether the time has not come when electrical engineers may arrange their plans for general electric supply on the assumption that incandescent lamps adapted to a voltage double that now in vogue will be forthcoming on demand, and whether there is good reason to believe that lamps of that kind will be as cheap and as good as the lamps for lower voltage. His paper raises other questions; in fact, it traverses a very wide field, and is very suggestive and interesting in many ways. But I am only going to speak—and that very briefly—on the point I have mentioned, and as to high efficiency.

I pass over, as Mr. Addenbrooke has done, the question as to whether there is a possibility of a different kind of lamp—a lamp, for example, of the Crookes tube or Tesla type—superseding the lamp now known. No one would be bold enough to say that a revolution of this nature is impossible, but at least it may be said that the symptoms of its near approach are not sufficiently marked to make it necessary for the electrical engineer to take the consequences into immediate account. It is, without doubt, a question of the greatest moment whether incandescent lamps of low candle-power, and requiring a voltage of something like 200 or 220 volts, can be made to compete in point of efficiency and cost with lamps of the lower voltage now in common use.

The demand for such lamps is comparatively a new demand, and Mr. Swan. as yet it is not a large one; but it is increasing, and the pressure is already sufficiently strong to compel the most strenuous effort to meet the demand in the way it is required to be met—viz., by the supply, at a moderate cost, of a lamp for double the voltage hitherto employed, and that shall have a fairly long life at a moderate efficiency. I think that is very nearly the way in which Mr. Addenbrooke states the question. Mr. Addenbrooke has told us that it is already possible to buy fairly good lamps of 8 and of 16 C.P. to suit from 200 to 250 volts. The lamps shown appear to bear out this statement. From my own experiments I know that it is possible not only to fulfil the very moderate requirements stated by Mr. Addenbrooke, but to go considerably beyond them; and as time goes on the difficulties which attend a new departure of this kind will undoubtedly decrease, and the result will be both increased efficiency and diminished cost. But in the meantime it must be remembered that the 220-volt 8-candle-power lamp is a more fragile thing than the 110-volt lamp of the same candle-power, and, as at present made, rather more costly to manufacture. Looking at the question from the point of view of the electrical engineer instead of that of the lamp manufacturer, it is fairly clear that these drawbacks have a sufficient, and perhaps more than sufficient, compensation in the additional facilities they give for a wider and more economical distribution of current from supply stations—a most important advantage, and one well worth making some considerable sacrifice to gain. But I hope the ardour for progress in this direction may not lead to the adoption of lamps requiring double the voltage of the lamps now in use in connection with already existing installations, except after the most thorough overhauling of all portions of the installation, including the wiring of the houses, coupled with the introduction of every safeguard against fire that good design and good work can give. In new work I see no other objections to high-voltage lamps, such as those we have now in view, than those Mr. Addenbrooke has named. He has given two years for the thorough elaboration of the higher voltage system. It is a very

Mr. Swan. liberal allowance. So far as the lamp manufacturer is concerned, he does not require it. If it is decided that, on the whole, higher voltage is necessary for the wider development of electric lighting from central stations, the lamp to suit the higher voltage will be duly provided whenever it is wanted, even if the time be now. To go from the question of high voltage to that of high efficiency, the real difficulty connected with the employment of lamps at a higher efficiency in watts per candle is not so much in the lamps themselves as with the conditions under which they are generally used, both in connection with the private and public supply of current. The fluctuations of pressure to which lamps are subjected are commonly too great to give a high-efficiency lamp a fair chance of life. At 2½ watts per candle the filament is of course heated to a very high temperature, and any rise in voltage above that which produces the 2½-watt efficiency is very trying to the life of the lamp; in fact, we all know that even the best lamps of this character will not bear for long any extra pressure, producing a super-high efficiency and a super-high temperature. The published charts made by the recording voltmeter show that, in the case of nearly all the public electric supply companies, the normal voltage is often exceeded by more than 5 per cent., and sometimes by even 10 per cent. When such extra pressure is brought to bear on lamps at the high normal efficiency of 2½ watts per candle, the result is disastrous: the lamps give way; but, given a voltage that never rises more than 1 or 2 per cent. above the normal point, there is then no difficulty in realising that degree of economy of current which Mr. Addenbrooke has described as obtainable by the use of 2½-watt lamps. Things will doubtless greatly improve in this respect, and I therefore hope that in the near future it may be practicable to make a much more general use of lamps of high efficiency than under existing circumstances would be either convenient or economical. I trust that, as everything that tends to the lessening the cost of electric light is to the general advantage, and promotes increased use, the occasional and temporary loss of revenue that would result from the more economical use of current by means of lamps of higher efficiency will not either be thought or found to be against the ultimate interest of electric supply companies.

Mr. C. H. STEARN: All who are interested in the extension of electric lighting owe a deep debt of gratitude to Mr. Baynes for the very courageous experiment which he tried at Bradford, and carried out under very difficult circumstances to so satisfactory a conclusion. Mr. Addenbrooke also, by his papers on the subject, has done good work in directing, at a very early period, the attention of the public to the advantages to be derived from the adoption of high-voltage lamps in central station lighting. If Mr. Addenbrooke had published the paper which he wrote two years and a half ago, at the time it was written, he would have fairly established a claim to have been considered as the pioneer of the high-voltage agitation in England. He published it, however, a little after Mr. Baynes had commenced his Bradford experiments. Both of these gentlemen, however, have exercised a material influence on the attention recently directed to the expediency of doubling the existing voltages on English electric light stations. Mr. Stearn.

I fully concur in Mr. Addenbrooke's view that the cheapening of electric light can be more easily attained at present by the use of incandescence lamps *at high pressure and low temperature*, than at *low pressure and high temperature.*

In the former case we have not the same difficulty to overcome as in the latter, viz., the more rapid reduction in light due to the changes at the surface of the carbon and of the glass.

So far as duration of the lamp is concerned, there is not much difficulty in either case; but when working at high temperature the change in the radiative character of the carbon surface, and the darkening of the bulb of the lamp, are far more rapid, even under the most favourable conditions, and are much intensified by the irregularities of pressure. With steady pressure fairly satisfactory results can be obtained with lamps of high efficiency; but, so far as the consumer is concerned, it will make little difference whether he pays 6d. per unit and consumes 2·7 watts per candle, or consumes 4 watts per candle at 4d. per unit, while in the latter case his lamps will be far less subject to deterioration than in the former.

But when the pressure on central stations becomes as steady

Mr. Stearn. as Mr. Addenbrooke hopes, then a still further benefit will be reaped by the consumer, as higher temperature can then be combined satisfactorily with higher pressure.

I must differ from Mr. Addenbrooke's views that increased pressure *necessitates* any sacrifice in the duration of lamps, either of 16 or of 8 candles. Careful experiments has shown that the duration of lamps of equal temperature (at least, at temperatures corresponding to from 3·5 to 4 watts per candle) is, if the filament be homogeneous, independent of its sectional area. I have not pursued the experiment for a longer period than 1,200 to 1,400 hours, as beyond that period the result would have no practical importance. If in some commercial lamps this result is not confirmed in some of those with the thinner filaments, the failure evidently arises from preventable causes.

The commercial results in the case of high-voltage lamps of 16 candles (3·7 to 4 watts per English candle) far exceed those obtained in the tests above mentioned, there being many instances of lamps of this type and initial efficiency lasting at 230 volts pressure over 4,000 hours without giving way. I do not mean to say that lamps that have attained this age are of any use whatever; on the contrary, it would be better, both for makers and users, if lamps came to an end as soon as their candle-power was reduced by about 30 per cent., or even sooner. I only quote these instances to show that the life of a 16-candle lamp, in commercial use, is not less at 230 than at 100 volts. These results also show that the efficiency might with advantage be pushed much higher than 3·7 to 4 watts per candle.

It appears to me, however, at the commencement of the change from lower to higher pressures, safer to wait till public confidence is fully established in the reliability of high-voltage lamps, before advançing to efficiencies higher than 3·5 to 3·7 watts per candle.

The difficulties in the way of the construction of high-voltage lamps are chiefly mechanical. Owing to the great length and small section of the filament, it is extremely difficult to manage in any reasonable compass, unless the construction usually employed in lamps of lower voltage is altered. By increasing the

specific resistance of the carbon we can reduce this length by Mr. Stearn.
about one-half; and if the filament be then supported in the centre, or—what is equivalent—if two filaments of half the length be used in series, as in Fig. 1, the filament is sufficiently rigid for

Fig. 1.

Fig. 2.

commercial use if employed, as incandescence lamps should be, in a vertical position; but used in a sloping or horizontal position, the filaments are liable sooner or later to descend and touch the glass.

When dealing with gas, installers obey the laws of gravity if they wish to preserve their shades; but the maker of incandescence lamps is assumed by many installers of electric light to be able to overcome entirely the effects of gravitation, so that lamps may be used in any position.

By making each loop in the form of an **M** or **W**, similar to that employed by Maxim some years ago (Fig. 2), much greater stiffness may be obtained, and high-voltage lamps of this type have been in use in a horizontal position for several hundred hours without any appreciable drop in the filament.

On the switch-board are shown three rows of 10 lamps each, which can be switched on in succession, the current of each set of 10 being shown on the ampere-meter on the top of the board, the

Mr. Stearn. pressure being shown at the same time by the voltmeter. The average consumption of energy by each lamp can thus be seen at a glance. The first row of 10 16-candle lamps reads at 205 volts, 3 amperes, showing the absorption of energy per lamp to be 61 watts. The second row of 8-candle lamps reads at the same pressure, 1·5 amperes, indicating an average of 31 watts each.

The lamps of the above-mentioned types are of the double-filament type, which, for many reasons, is the most convenient as a transitional form; but there is no doubt that the single-filament will ultimately become the predominant type.

But, to render the single-filament commercially successful, the existing types require a modification even more radical than the double-filament, as, owing to its great length and flexibility, it must either be shackled, or else it will speedily come in contact with the glass with the slightest vibration or electrification of the glass surface. If wound into several spirals there is still great danger of the convolutions coming in contact with each other.

Fig. 3.

Fig. 4.

In the lowest row of lamps (Figs. 3 and 4) is shown an attempt to overcome the mechanical difficulty, and to construct a single-filament lamp that shall be self-supporting and capable of

being used safely out of the vertical position. The filament is first wound in a sinuous curve, and is then bent into an arch at right angles to the plane of the curves: we have thus a resistance to movement in two planes at right angles to each other. By using a construction of this kind we can put any length of filament that may be desirable into a small bulb. Besides the additional rigidity, there is another advantage gained by the sinuous filament. The change in candle-power is no doubt slower at the same efficiency if carbon of low specific resistance and low emissivity for light is employed, than if we use the filaments of higher specific resistance and of greater emissivity. As the mechanical objections to the employment of low-resistance carbon are thus overcome, we can push the efficiency higher with the same rate of descent in light. (For the suggestion of the above form of filament I am indebted to Mr. C. F. Topham.) With regard to the probability of the diminished life of lamps that Mr. Addenbrooke has touched upon, I cannot see any theoretical reason, independently of the practical trials I have referred to above, for supposing that lamps of the same candle-power and efficiency will last any shorter time at double than at single pressure. Mr. Stearn

Satisfactory commercial results have for a long time been reached with lamps of 3, 4, and 8 candles at 100 volts. If you put two filaments of the same kind in a bulb, it is immaterial whether you use them in parallel or in series—the conditions of duration are in no way changed. In the first case you have two 4-candle filaments at 100 volts, and in the second two 4-candle filaments at 200 volts.

If the manufacture of the filaments is of the best quality, only a small percentage fail under 800 to 1,000 hours, except from undue mechanical strain, or damage in transit, or over-running.

The movement in favour of high voltages has now attained such strength that there is little danger of its being abandoned; the slight opposition offered to it by those who are a little timid will soon die away after a short experience has shown that their fears are groundless. The same arguments now used as to the non-reliability of lamps of 200 volts were used at the commencement

r. Stearn. of the industry in 1881–1882, when we passed from 50 to 100 volts. A little later, when the 8-candle lamp at 100 volts was introduced, we heard the same doubts expressed as to its commercial durability as are again repeated when lamps of 200–230 volts are spoken of. But in spite of this the 100-volt system has supplanted the 50-volt, and as certainly will it in its turn have to give place to its double.

The 8- and 6-candle lamps at the higher pressures will also, I venture to predict, be as firmly established in popular favour 12 months hence, as the corresponding lamps of half the voltage now are; and we shall all then wonder, as we look back, why we were so slow to adopt so obvious an improvement, and made so great a difficulty of so simple a matter.

Before I sit down I will read an extract from a letter from Mr. Gibbings, the borough electrical engineer of Bradford, on the results of the use of a high-pressure system in Bradford, after several months' experience:—

"It may be of further interest for you to know that we have "about 160 customers who have been using high-voltage lamps "for over six months, and our other consumers have positively "been coming to us in dozens asking to be changed over to a "higher pressure."

Ir. Rose. Mr. T. A. Rose: I have very little to add to what Mr. Stearn and Mr. Swan have said. I have made a speciality for some years past of the manufacture of high-volt lamps, and I am glad to say that my experiments have resulted in a commercial success.

The lamps my company have on exhibition this evening show two distinct forms of manufacture, viz., a specially designed single-filament, and the more usual double-filament type. Both these systems possess advantages; but, from a technical point of view, I believe the single filaments are the best, as they possess greater uniformity throughout their length; while, on the other hand, the double filaments are more suitable when the lamps are run in a horizontal position, as they possess greater rigidity, and can be placed in a smaller bulb.

The durability of a 200-volt lamp is naturally not as great as that of a 100-volt lamp of the same efficiency, in accordance with

the known fact that a 100-volt lamp is not as durable as a 50-volt lamp, or a 50-volt as a 5-volt lamp of the same efficiency. For this reason, a slightly lower efficiency should be allowed a high-volt lamp. Personally speaking, I always advise an efficiency of 3·5 to 4 watts per C.P. for high-volt lamps, where I should advise an efficiency of 2·5 to 3 watts per C.P. for the usual low-volt circuits. Mr. Rose.

Mr. J. F. C. SNELL: At the King's Road station, St. Pancras, we are running entirely at a pressure of 220 volts—that is, a three-wire system with 440 volts between the outer conductors. At the present moment we have about 4,000 lamps fixed, and the greater number of them have been running now for about five months. We have had very little trouble indeed with them, and I do not think the consumers really know the difference between the 200-volt lamps and the 100-volt. My experience of them has shown me that manufacturers require to make some alterations in the cut-outs and in the holders. It is in the holders that we have the trouble, from short-circuiting between the contacts, or between the contacts and the brass case. With reference to the life of high-voltage lamps, I have had some running at my house, and they have been running now for over 1,300 hours. This, I think, will compare very favourably with the 100-volt lamp. There is one point which we have to consider in the use of this higher pressure: under the new Board of Trade rules we shall certainly have to earth the centre wire on a system like the above; and I think some one at the Manchester meeting of the Mechanical Engineers pointed out that you, Sir, found a considerable leakage resulted between the earthed balancing wire and the negative, due to the collection of moisture at the latter—*i e.*, to osmosis—and I do not know how we are going to overcome that difficulty. Of course this will not obtain with the ordinary 110-volt supply. With regard to steadiness in pressure, the Board of Trade now permit us to have a variation of 3 per cent. above or below the standard pressure. On a 440-volt supply (such as a three-wire system of 220 volts on each side of the balancing wire), I think it will follow that it will be very much easier to obtain a greater steadiness of pressure—*i.e.*, a less percentage variation Mr. Snell.

Mr. Snell. at the lamp terminals—than we now obtain with a 110-volt supply. That being so, I should say it would conduce to the life of the lamps.

Mr. Robertson. Mr. C. J. Robertson: The lamps with which my name is identified I see, unfortunately, have not been able to burn, owing to a cut-out having gone; that, I take it, is no fault in the lamps themselves. The troubles the Incandescent Electric Lamp Company have found with high-voltage lamps up to the present are *nil*, except with the people who handle the lamps in the course of manufacture. Very high voltage is necessary in the manufacture of low specific resistance filaments, such as I imagine are the only practicable filaments to be used. Beyond that I pretty well agree with what Mr. Swan and Mr. Stearn have already said upon the question. We, like others, have had very small experience; but, up to the present, we are perfectly capable of instantly converting the whole of our manufacture to 200, or even 300 volts, if so required. The danger which I pointed out as to manufacture is a question which each manufacturer will be able to get over as he approaches the higher voltage that may be called upon; but certainly, as I have before said, there are no unsurmountable obstacles from a lamp-maker's point of view.

Mr. Geipel. Mr. W. Geipel: In the first place, I think we are indebted to Mr. Addenbrooke for having made the calculations as to the cost of the cable distributing plant on the three-wire system at 200 volts. He makes the cost per kilowatt for the distributing plant alone come to £60. Now that figure is quite sufficient to cover the whole cost of any alternating station on the 100-volt system. The question of first cost in the working of a central station has a singular importance on the cost of the supply to the consumer, and needs no emphasis on my part. I worked out a curve, which the members will find in the discussion on Mr. Crompton's paper, showing the enormous influence of first cost on the cost per unit. For example, when the plant cost 2s. 9d. per unit sold, the cost per unit for standing charges was 3¾d.; whereas, when the cost was reduced to 6d., the cost per unit came down to 1¾d. I think, if Mr. Addenbrooke's estimate is correct,

there is a long life before alternating work, and those who have given their time and attention to developing that system may rest satisfied that they have not thrown away their labours. Mr. Geipel

Mr. ADDENBROOKE: That figure is only given supposing we get a distribution up to 2½ miles from the station, and supposing that the population density and the amount of supply for the whole area is the same. There is scarcely any station at which it would apply. Of course it will come out much under that.

Mr. GEIPEL: As a matter of fact, you have taken the most advantageous case: you have taken the case of a central station right in the centre of your distribution; and you have taken a populous district, which, of course, is all to your advantage. But, if you will consider the matter, you will find that it is much more advantageous to work a station when it is outside a town—not only on account of the immunity from legal action, but also because you can get cheaper ground, you can get condensing water very probably which you cannot get in the centre, you can get your coal easier; in fact, there are many advantages in having a station outside a town which you do not get if the station is in the centre. That is all in favour of the alternating system. I think there are no gentlemen here who will deny that the 50-volt lamp can be run at a higher efficiency than the 100-volt lamp, and also that the 100-volt lamp can be run at a higher efficiency than the 200-volt lamp. A great deal has been said about the manufacture of 200-volt lamps, but I want to know at what efficiency those lamps are calculated, because, if you like to run a lamp at 6 or 10 watts per candle, you can get it to last for ever. I was very much interested in seeing Mr. Stearn's excellent method of strengthening the filament of the 8-C.P. lamps. I should like to ask him why he cannot use the same idea in making good 8-C.P. 100-volt lamps. I do not know whether most of you have had the same experience with 100-volt 8-C.P. lamps as I have had: if you have, you will be very anxious to see whether this improvement can be adopted; and perhaps Mr. Stearn, or some other gentleman, will tell us whether such improvement cannot be so accomplished. Mr. Gibbings has written a very flattering letter as to his consumers'

Mr. Geipel. satisfaction with 200-volt lamps; but he, again, does not refer to the question of efficiency, and it is possible that his consumers have not yet had their accounts. I also suggest that the reason why these consumers are so pleased at present is that, whilst with the 100-volt system they had a notoriously varying pressure, with the 200-volt system they now get constant pressure. Of course that is what one might expect, because we know that the capacity of the mains is increased fourfold when you change to 200 volts. But the consumers at Bradford, at any rate, I take it, have not yet found out at what cost!

I do not believe that the 200-volt lamp is the correct lamp to use; in fact, I quite agree with Mr. Addenbrooke that it is in the tentative stage, and I fear it will remain there for many years to come.

We all know that, apart from all questions as to economy in watts per C.P. and as to the necessity of small candle-power, lamps can be made and used successfully very much higher than 200 volts; but then people cannot all afford to use "sunbeam" lamps in their little dark corners, especially in those places which require artificial light all day. The question, to my mind, resolves itself upon the 8-C.P. lamps. People ought to have the advantage of using such lamps without wasting half the energy by burning another lamp in series with it, as has been suggested, for they might just as well use the 16-C.P. lamp at once.

Can lamp-makers produce a good 200-volt lamp of 8 C.P., which will last 600 or 700 hours with a strain of 3 watts per candle? My experience is that they cannot do it. I doubt if it can be done with less than double that strain; indeed, it is difficult enough to obtain efficient 100-volt 8-C.P. lamps which will stand satisfactorily the ordinary varying pressure of an electricity supply works. A great deal is made of the improvements which have taken place, and which may be expected, in lamps. He would be a bold man who stated that advance were an impossibility; but has this wonderful improvement actually taken place? Ten years ago good 100-volt 16-C.P. lamps could be obtained, using 4 watts per candle, and lasting 1,000 hours. It may be that this strain has been reduced to 3½ watts per candle

for a similar life, but I think that is about the extent of our improvement. Of course the price has been so much reduced that it pays to use lamps at a higher efficiency, but the improvement in the quality does not appear to be so wonderful. Mr. Geipel.

For my part, I think this 200-volt lamp policy a mere subterfuge, which should be strongly opposed. Why are people adopting the Welsbach gas burner? Simply because they get a good light for half the consumption of gas. If, then, we wish to compete with the Welsbach—and it is a serious competitor—we must give the consumer a lamp which takes less watts; in fact, the tendency, if anything, should be to reduce the 100-volt supply rather than to increase it to 200 volts, for I think no one will deny that with the lower voltage more efficient 8-C.P. lamps can be made. It is my opinion that the popularity of the electric light will be distinctly and unfavourably affected if we force upon the consumer a 200-volt supply.

Mr. L. EPSTEIN: Inasmuch as the figures contained in the author's paper are borne out by my own experience, I really have no fault to find with them. I think that what Mr. Addenbrooke says about the cheapening of accumulators is well founded upon facts; and, inasmuch as we all anticipate that the last word in the cheapening of accumulators, or in the way in which accumulators can be used to the best advantage, has not been spoken yet, I think we may anticipate further advantage to cheap distribution arising also from that source. Mr. Epstein.

Mr. A. A. CAMPBELL SWINTON: May I make one remark in relation to what Mr. Geipel has said? Mr. Geipel has touched upon the question of the efficiency, which, of course, is a very important point, but I think what he said wants to be carried one step further. We are told that the efficiency of a lamp is so many watts per candle. Now what does the "candle" mean? There are two candles—there is the German candle and the English candle—and I must say that personally in many cases I have been much puzzled to know to what particular candle the lamp-makers refer. I am not speaking of the difficulty of measurement—there are great difficulties in the really accurate measurement of the candle-powers of incandescent lamps—but I Mr. Swinton.

Mr. Swinton. refer to the standard. There are two standards, and I think it is very desirable that we should have only one standard, for then we should know more definitely what we are talking about.

Mr. Patchell. Mr. W. H. PATCHELL: I have not had much time to read this paper, although it was sent me about a week ago; but, looking over it last night, it struck me as a paper of extreme moment. There are several things in it which touch central station practice very pertinently. I have been anxious for some time to introduce a 200-volt lamp, but have first tried to get a lamp at the same price as the 100-volt lamp. It would be of manifest importance to every station engineer if he could double his pressure: the capital value of his mains would be increased; but when a consumer came to pay the bill for lamp renewals, I think the company would have in some shape to subsidise him, or find him the 200-volt lamps at a loss. Whether that would pay the company at the present moment is a moot question. I really think, as we have so many lamp-makers in the room, that we ought to impress upon them the necessity of having the double-pressure lamp at the same price as the single-pressure lamp. I have been surprised to hear 100-volt 8-candle-power lamps run down. We have had no trouble with them running at a steady pressure, and all I can suggest is that the people who have had trouble with these lamps have not run them at a steady pressure.

Mr. Handcock. Mr. H. W. HANDCOCK: I do not wish to carry the discussion any further in the present groove, except to call your attention to a little experience of ours that occurred a few days ago. One of our clients, living not far out of London, was always complaining about the lamp filaments going. It was rather a mystery to us, and at last we said, "The best thing you can do is to see the "engineer at the central station." He did so, and was advised by him to use 110-volt lamps instead of 105. Now that is rather suggestive, considering that the voltage of the circuit was 105, and I must ask you to draw your own conclusions. We have heard a great deal about the satisfactory life of 200-volt lamps, and I think we have had demonstrated to us very obviously the advantage from the central station point of view. But we have not heard very much from the consumer's side. Possibly we

should first have before us relative figures. We want to know the efficiency of, say, an 8-C.P. lamp at 50, 100, and 200 volts respectively, and also the candle-power of lamps for these different voltages at the end of 500 hours. Our experience would rather indicate that with 100 volts the limit has been about reached. Occasionally one gets extremely good lamps; but when we go far above that voltage we have continuous complaints from clients about filaments going, and the uncertainty of their life. If the voltage was steady it would be quite a different thing, and I think that the inventor of the incandescent lamp struck the right nail on the head when he referred to the very great fluctuations of voltage prevalent on many supply systems. For instance, a certain make of lamp may be recommended for one circuit, and give no trouble at all. We may take a portion of the same batch of lamps and send them on to another company's circuit, and there is an endless trouble; their life is a mere nothing. Possibly the trouble might be got over—if a 200-volt lamp is finally adopted—by doing much the same as they do in New York. I was very much impressed with their photometric arrangements there. As things are at the present moment here, 90 per cent. of the trouble with consumers is due to faulty lamps, and this has been got over at New York by the company including in their rates the lamps themselves. Every lamp goes through their laboratory and is carefully tested in the photometer, those that do not come quite up to the standard being rejected and sent back to the makers. I cannot help thinking that, if we adopted something of the same system here, the gain would be very considerable. Going back to the question of the relative efficiency of lamps, I should like to ask, now we have so many central station engineers here, whether, if they double their voltage, they are going to supply the consumer with current at such a rate that for the same amount of light his account will be the same with 200 volts, instead of 30 or 33 per cent. more than what it is now? Then the consumer has a right to say a word about increased cost due to installation and price of lamps at these increased voltages. Some years ago I was rather closely connected with 220-volt installations, and the fittings, such as were then upon the market, were a

Mr. Handcock.

Mr. Handcock. continued source of trouble. Our 25-ampere switches would not switch off; our cut-outs arced right across, and blew the covers to pieces; the main fuses, if there were any covers on them at all, blew all to pieces also; and altogether we had a very unpleasant experience. Certainly it was not because we went in for cheap fittings—we had the best obtainable; but still there was far more trouble on the 200-volt circuit than we had on the 100. The 200-volt circuit, for some reason, is very apt at finding out faults; but if makers will only remodel their accessories, such difficulties as I have just mentioned should be entirely obviated. I am also of opinion that where the voltage is 200, single conductors should be prohibited entirely and replaced by stranded ones.

Mr. Rawlings. Mr. W. R. Rawlings: If we are to compete against gas, it seems to me that we should have small candle-power lamps. Very often I am called in and asked the reason of the enormous electric accounts. Very often one finds in an out-of-the-way place—a water-closet or a coal-hole—a 16-C.P. lamp burning, simply because that lamp has a long life. If you reduce that lamp to a 3-C.P. lamp—which some of the 100-volt makers have been giving us of late—and put on 8-C.P. lamps where a little more is required, you then reduce the electric account to something reasonable, and comparable with gas. There are many places where a small light is required, such as a dark passage in a basement. Only a short time back a case in point arose. The question was whether it would be more economical to let in daylight, or burn a small incandescent lamp continuously; and it was found that a 3- or 5-C.P. lamp worked out much more cheaply. It occurred to me that that would be a very great source of income to electric light companies. But had it been necessary to burn a 16-C.P. lamp, that would never have happened. I should like to know if lamp-makers can give us a good lamp with 3 C.P., or even less, for 200 volts. If so, I think we should overcome the difficulty. But if we look upon the minimum as an 8-C.P. lamp, I am afraid that we shall still be troubled with these heavy electric accounts.

The President. The President: Manchester has been referred to by one of

the speakers. In Manchester they have had now for three years experience of working at high voltage. In the Town Hall they are actually working at 400 volts, for they take all five wires there. According to circumstances they use, one, two, three, or four lamps in series, and they have large groups of four lamps in series for lighting the public rooms. They have had no trouble whatever in connection with the wiring there. Of course care was taken in the first instance not to put in fuses which were intended for 100 volts for 400-volt purposes. Special fuses were arranged. But from the beginning there has been no trouble, and no changes have had to be made. The same system exists in other places in Manchester. There are other places with five wires, and others where there are three wires, and instances where there are a large number of lamps which are arranged in series, and where there is in actual fact the 200 volts on the terminals, and no trouble has resulted in any case. So I think we may be certain, as far as the wiring is concerned, that we have nothing to fear in working at the proposed system of 200 volts. The question of leakage has been referred to. In Manchester, it is true, from the negative terminal, there is a substantial leakage; and that exists, and always exists, because the middle wire is bound to be put to earth. That, of course, really arises from the fact that bare copper is used to a very considerable extent. It is now being used to a greater extent, on account of the very great facility it provides for making connections and avoiding vulcanising joints. So far, it has been found to be a success. The leakage does not cause any inconvenience at all, but of course there is a certain loss of power from that leakage. Mr. Addenbrooke has referred to the use of accumulators, and particularly to the use of accumulators at out stations; and he has pointed out that, if you require to increase the capacity of a main, you can do so by putting an accumulator at the end of that main and charging it. It really amounts to this—that, comparing an out-station accumulator with the corresponding generating power at the station, you should compare its cost with the cost of the boiler, the engine, the dynamo, and the

The President.

The President. feeder, because you are enabled to make use of a feeder through very much longer hours; and the real effect is that you increase the radius at which you can work, and largely increase the extent to which you are able to use your copper. There is an additional incidental advantage in the use of out-station accumulators, and that is, that you get such very great facility for regulation: you can regulate your pressure at the end of that feeder to the extent of the step of one cell. I will now call on Mr. Addenbrooke for his reply.

Mr. Baynes. Mr. SYDNEY BAYNES [*communicated*]: I regret I am unable to join personally in the discussion, in consequence of a special meeting of the St. Pancras Electricity Committee having been convened for this evening. Under these circumstances, Mr. Snell has kindly undertaken to read my remarks on the paper now under consideration. As I believe I have had the privilege of being the first to employ lamps of high voltage in electrical distribution, a short summary of my experience may not be without interest. It will be necessary to revert for a few moments to a period which, so far as electricity supply works are concerned, may now be termed ancient history. In those days it remained an open question whether central stations would ultimately become a source of revenue to municipalities or not; in consequence, the expenditure was limited and meagre in comparison to the handsome sums now freely voted by municipal bodies. Shortly after the opening of the Bradford installation in 1889, it became evident that the mains were likely to become loaded in a much shorter time than had been anticipated. It thus became a pressing question with me in what manner I could increase their carrying capacity with the smallest possible capital outlay. After carefully going into the matter, the most promising solution of the difficulty seemed to lie theoretically in the adoption of a three-wire system, with lamps at 230 volts. The three-wire system was already in the market; not so a lamp to suit my purpose. Feeling confident, however, that the lamp was but a question of time, I made ready for its adoption by giving personal attention to every detail in the wiring of premises, and prohibiting the use of double-pole cut-outs, so that, when the day

came for the fulfilment of my expectations, there should be no cause for anxiety in connection with the consumer's premises. I can only touch briefly on the initial difficulties in procuring lamps. After persistent inquiries and interviews, I managed to procure small consignments from several makers. Only one design of lamp, however, survived the tests satisfactorily at that date. After further considerable delay, another firm entered the field, and supplied a good lamp; but it became apparent that to achieve any degree of success it would be necessary to encourage the manufacture of such lamps on a commercial scale, and, as I was now satisfied that two makers could be relied on, I resolved to give effect to the scheme which I had so long hoped to put into practical use. Accordingly, I issued notices intimating that all future consumers would be supplied at 230 volts. There still remained the terms of the Provisional Order to consider. The most diplomatic method of dealing with the difficulties therein presented appeared to be, first, to prove the practical utility of the double pressure, and then leave the matter for the consideration of the Board of Trade. I therefore used only the outer conductors as a pair, and thus maintained the spirit of the Order. I have to acknowledge my indebtedness to the Board of Trade in allowing me a certain latitude, wherein I had time to demonstrate the practicability of the innovation. At an early stage in the working of the scheme, I had numerous inquiries from America as to lamps, and the measure of success achieved. I now learn that in the comparatively short time which has elapsed there are over 15 central stations in the United States working with 200-volt lamps. We are not yet in a position to report such progress on this side of the Atlantic—a striking instance of British caution contrasted with Yankee go-aheadness. Now, in regard to the question of current-density, I would suggest that Mr. Addenbrooke is too liberal with his allowance of copper. I prefer to allow for a 2 per cent. variation, with distributors extending 880 yards from the feeding centres, and working at a current-density of about 700 amperes per square inch. The pressure should be gradually increased to 2 per cent. above the normal at the feeding point as the load approaches maximum,

Mr. Bayn

Mr. Baynes. while the pressure on the distributor at the far end would fall 2 per cent. below the normal: thus, by a judicious compromise, we are able to limit the variation at the lamp terminals to 2 per cent. In this way the number of feeding centres would be reduced to a minimum, and might be spaced at intervals of a mile. The generating station would feed direct into the network up to a half-mile radius, and the distance in any direction to 2½ miles would be readily dealt with by throwing out two feeders into the district to be supplied. The near feeder would obviously be worked at double the current-density, so that both the near and far feeders would be coupled to one common bus bar. It would be advisable on the score of economy to serve the home portion of the network from a separate bus bar, as the voltage would only be required to exceed the normal by 2 per cent. at maximum load. It being usual to place feeding centres where roads intersect, there would be eight distributors, each extending 880 yards, or a total frontage of 7,040 yards. Allowing for branch streets, we might readily count on a lamp density of three lamps per yard. This would represent about 3,200 amperes at 440 volts to be delivered to each feeding point. It would be preferable to divide this current amongst four separate conductors constituting the feeder.

This method of grouping the conductors simplifies the regulation and allows for the adjustment of varying pressures by switching off portions of the feeder should any irregularity occur between the feeding centres. The facility in regulating thus afforded would be considerably augmented by a judicious selection of the sectional areas of the cables combining to make up the feeder. Very shortly the King's Road Works will be supplying current with the distributing network extending a total distance of nearly 2¾ miles to the furthest lamp. The current-density on the feeder will be heavier than that laid down in the paper under review. I may here remark that, providing the centre network of the distributing system be brought back to the generating station, and reasonable care taken to balance the distribution of lamps, there appears to be no necessity for a centre feeder. In regard to the possibility of using lamps of high

efficiency and low voltage, since the regulation at the increased pressure would approach much nearer the ideal than has hitherto been obtainable, these lamps could be adopted two in series with a success and certainty which is quite impracticable on a system run at 110 volts. The tendency in shop-lighting is to group several lamps on a switch, so that it would make little difference whether they were burning in series-parallel or otherwise. If a really reliable high-efficiency lamp could be obtained, any waste of current inevitable from the necessity of burning two in series would be a mere trifle compared with the economy effected by their use. Mr. Bayne

Now as to lamps of high voltage: Those makers who have devoted both time and money in perfecting their methods have been remarkably successful in producing lamps of comparatively high efficiency, averaging from 3·3 to 4 watts per C.P., whilst the average life already greatly exceeds that assumed in the paper. I consider the profession is under an obligation to several of these manufacturers for their persevering efforts to keep pace with the requirements of the electrical industry, and in their courteous endeavours to deal with and remedy any defects that have occurred during the development of the lamp; but for their able assistance and co-operation we should not be assembled to-night to discuss this very interesting paper. As to the question of fire risks, where the wiring has been well done there is undoubtedly less risk than with the lower voltage—1st, because the fuses are lighter; 2nd, should an arc occur across the casing, the current would more readily exceed the carrying capacity of the fuse. In the St. Pancras installation we limit the current through any pair of mains to 25 or 30 amperes, and, as each circuit is protected by the Vestry's standard fuses, kept under seal, it is immaterial whether or not any fuses exist on the branch circuits. The rule that no conductor shall be smaller than a No. 18 S.W.G. renders a 220-volt supply absolutely safe though not a single branch cut-out existed on the whole system, because you may short-circuit and blow the main 30-ampere fuse through a No. 18 S.W.G. insulated conductor without damaging it in the least. Cut-outs in ceiling roses are useless; the branch

Mr. Baynes. cut-outs—one on each pole, with an inch, or certainly not less than ¾ inch, of clear break—should be relied on. Double-pole cut-outs should not be permitted, as they are liable to short-circuit. Main cut-outs at entrance of buildings should have, by preference, 1¼ to 1½ inches of clear break. No trouble whatever has been experienced with any switches or other fittings. It is regrettable that the insurance companies still acknowledge the use of casing with the conductors kept at about an arcing distance apart. Practically, this is wrong; the conductors should be kept in close proximity: then, on the failure of the insulation, instead of an arc springing up and continuing (as I have known it to do on 115-volt circuits), a short would occur, at once blowing the fuses. I am unable wholly to concur with Mr. Addenbrooke's remarks as to the effect on alternating-current practice. As the most modern systems now employ a distributing network, the introduction of a higher voltage lamp would be a distinct advance for either system.

Mr. Addenbrooke. Mr. G. L. Addenbrooke: It is rather a difficult matter to reply to such a very large number of points as have been raised by the various speakers at such a short notice, and, therefore, I should be glad to have an opportunity of considering the remarks afterwards and sending in my reply a little more categorically than I shall make it now. In the first place, I perhaps ought to have mentioned in my paper my indebtedness to others. It was at the suggestion of Mr. Crompton that the subject was put in the form of a paper at all. My first idea was a simple article sent to one of the journals. On mentioning the matter to Mr. Crompton, he said he thought it was worth a paper, and he would like to see what I had written on the subject. The unfortunate fire that occurred at his works prevented him taking so much interest in it as he would have done; but, still, he saw the proofs more than once, and made important criticisms on them, and there are some valuable suggestions in the paper which are due to him. I know he was very anxious to be here to-night at the discussion, and no doubt he would have given us some very valuable hints on the subject. Unfortunately, however, he has been called abroad. I am also indebted to my

partner, Mr. Ernest Scott, who has gone through all the figures and checked everything, and made the diagram; and to Mr. Callender, who has prepared the table relating to conductors; and to Mr. Epstein, who went to considerable trouble in looking up contracts and various things to ascertain the amount accumulators had come down in price in the last few years. Mr. Addenbrooke.

There is just one point I should like to refer to which has not turned up in the discussion. I mentioned in my paper a certain proportion of 8-C.P. lamps to 16-C.P. lamps, and I must say, following out some of the earlier experiences, I was under the impression that the number was very considerable; but, in conversation with Mr. Swan the other day, he said that I appeared to be under some misconception on the relative numbers, and from what he could speak off-hand of the sales of the Edison-Swan Company, the 8-C.P. lamps did not amount to much more than a quarter of the 16-C.P. lamps, speaking generally.

Mr. Swan: Yes, that is so.

Mr. Addenbrooke: I think that is a very important point. If, after so many years of use, the Edison-Swan Company, which has enjoyed almost a monopoly until the last year or two, has found that comparatively so few 8-C.P. lamps are used, then the argument against the 200-volt lamps is taken away, on the score of the difficulty of getting 8-C.P. lamps. I might also remark incidentally, Is it not a great pity that central station engineers will insist on calculating all their results on the basis of 8-C.P. lamps, which we know are a most uncertain thing, when we have the much more reliable basis of 16-C.P. lamps, of which there are four times as many in use as 8-C.P. lamps? No doubt the present custom was brought in in the earlier days, when central stations liked to see as many lamps as possible on their circuits; but I think this is a little ambition they should have outgrown by this time, or may outgrow very soon.

There is one very curious thing about this double-voltage question which has always struck me, namely, Why have not we had an intermediate voltage? We are told by the makers that they can make us a 220-volt lamp; the same

Mr. Addenbrooke. figures I have given apply, though certainly in a modified sense, to 150-volt lamps. The 150-volt lamps allow of distribution over double the distance that the 100-volt lamp does, and of course that itself would be an enormous gain. It is very curious that in this country we have not had 150-volt lamps in the market. They would be exceedingly useful for lighting factories, and for a great many other purposes quite outside central station practice; and although, no doubt, it would be inconvenient for some central stations to change to 150-volt lamps, there are fresh central stations starting up every day, and there are alternating stations, too, in which the change might be made. I believe lamps of these voltages are much more largely used on the Continent, however, and that in Austria they are working a considerable number of lamps at 150 and 160 volts; but apparently we are going to make a big plunge right away. Professor Kennedy at Edinburgh is changing over the whole system to 230 volts; and I believe that the Westminster Company are already offering their customers to change their lamps for 1s. 3d. each, and give them a certain guarantee if they will go over. I speak without official data, but I fancy that the London and County Brush Company have determined to light the Wandsworth district with 200-volt lamps; and the lamps are in use, or going to be in use, in a very large number of other places. I may say Mr. Shoolbred told me at the last meeting that he was carrying out the Birkenhead installation with these lamps, and found that the calculations came very near those I have given you in my paper.

There is one thing which this debate has brought out, and that is, that we have actually seen the lamp-makers and heard them speak. I do not think, as far as I can recollect—I speak under correction—that really since Mr. Swan brought out the lamp originally, we have ever heard so much from lamp manufacturers. There are, no doubt, a great many electrical engineers who have been feeling their way in the dark, to a great extent, with regard to this lamp question. Until Mr. Robertson very kindly showed me over his lamp factory about six or eight weeks ago, I had never seen incandescent lamps made, and I daresay that is the same with very many other engineers. However,

we really are getting to the other side of the question to some extent; and I cannot help thinking that the debate to-night, considering the authority of the speakers, will do a great deal towards telling electrical engineers what is the position of the incandescent lamp, and what are the points and difficulties about its manufacture and life. We do not want to bear hardly on the lamp-makers. If there is a difficulty which they cannot meet, if they tell us of it, we will try to meet it on our side; but if there are things they can get over, and which would be of great help to us, no doubt it would be a great advantage to both to try and state the case clearly. Mr. Addenbrooke.

Mr. Swan has spoken about fluctuations of voltage. This has been a sort of pet subject of mine for a long time, and I have referred to it in a good many forms. It is very much greater than central station companies like to acknowledge, and it is one reason why, up to the last year or two, I have been in favour of alternating currents. It seemed to me it was possible with alternating currents, if you were forced to use 100-volt lamps, to get better regulation than you could by the continuous-current system—at any rate, if the area was at all considerable. That is a good deal altered by having 200-volt lamps. In the experience I have had of 200-volt lamps, I believe, and feel sure, that they are a good deal less affected by slight changes of voltage—at least, that was so with the particular form of lamps I tested—than 100-volt lamps. I may say that we were testing some oil engines a few months ago which were not very steady, and we were not able to keep the voltage down, and once or twice they ran our voltage up to 300 volts. Some of the lamps were horizontal, and the filaments bent over. They seemed half fused. The filament did not give way, it simply bent over just like a piece of iron that has got red hot. In one or two cases it touched the side of the lamp, and was soon gone; but in one or two cases it did not, and for some time afterwards burnt in that bent-over form. I am sure that Mr. Stearn's remarks will be much appreciated. He has made high-voltage lamps a speciality, and certainly *this* (his corrugated filament) form of lamp is exceedingly pretty; and I think, when you have an opportunity of examining it—as

Mr. Addenbrooke. you can do after the lecture—close to, you will readily see that it is a thoroughly practical lamp. It is a class of lamp that would be very nice for 100 volts also. You get the light more concentrated, and there is not that spidery effect that you find about the ordinary incandescent lamp. There is another point on which I would like to make a few remarks. Many 220-volt lamps contain two filaments, and there is a sort of supposition which is jumped at that if you have two filaments in a lamp—I think I have seen this in print—say two 8-C.P. filaments, put in to make a 16-C.P. lamp, the life of the lamp on the average will be about half what it would be if there was only one. But that does not follow at all, if you come to think of it. If the average life is 800 hours, perhaps one of these filaments may go in 700 hours, but the two together would last 700 hours; whereas half is only 350. So it is not true that the life of the lamps would be halved by using two filaments.

Mr. Geipel: I suppose you have no better figures from actual experience than what you give here as to the cost?

Mr. Addenbrooke: I know what the costs are, but it is not usual to give them at these meetings, and you could get that from the lamp-makers direct.

Mr. Geipel: I mean the cost in life which you put in the paper.

Mr. Addenbrooke: I think that is a very outside figure. My feeling in writing the paper has been to keep largely inside on every point, and I believe that if I had tried to stretch the thing I could have stretched it to nearly double by adding a little on here and a litle on there. But I thought that the gain was sufficient if I took it as it stands now, and as it stands now I think there is very little one can say against it. Perhaps that will lead me to pass on to Mr. Geipel's remarks. He speaks of £60 a kilowatt as my estimate, and I have briefly pointed out that that estimate was for a station carrying feeders 2¼ miles, with network, and it assumed that the density of population was the same over the whole area. If you count the squares round the outside of that diagram, for instance, you will see that a good deal more than a half the lighting will be at the greater length.

I should have put some further figures in on that point, but I thought that it would make the paper too long. But if you will take a diagram like the figure, drawn on a piece of tracing paper to scale, and will lay it on maps of most of the towns of England, or nearly all the towns except London, you will find that mains 2½ miles long will go a long way into the suburbs. Even supposing you put your central station half a mile out of the centre—and you might even in some cases put it a mile—although the cost would be slightly increased, it would amount to very little more; and therefore that £60 per kilowatt is a very outside figure indeed. I meant it to be an outside figure, but at the same time it is enormously inside what is being done now. As regards alternating stations, some figures have been put into my hands lately. There is a station which is prominently before people now—the Islington station—where, I am told, the cost per kilowatt amounts to £212. Mr. Addenbrooke.

Mr. GEIPEL: That includes, no doubt, the provision for extension.

Mr. ADDENBROOKE: That includes, no doubt, some provision for extension; but then we must consider how much has to be spent on distribution in extension. No doubt that is a very outside figure; I am quite willing to admit that, but at the same time there it is. Then Mr. Baynes has given you some practical figures of mains. I wished to take a very low loss, and I have taken a lower loss than Mr. Baynes considers desirable, and that is a question for consideration. If you want to have a very even pressure, very small falls—which all the lamp-makers tell you is necessary in order to get the most perfect form of lamp, and enable them to give you the most economical lamp—then you want a good lot of copper. Even at 250 amperes to the square inch the copper comes out at a very moderate figure. Mr. Baynes, by allowing a rather greater fall and working at a greater current-density (he has actually got mile areas fed from one radiating point or one feeder point), has still only got a drop of 2 per cent.; and there is no doubt whatever, if you worked out a central station that way, that the cost per kilowatt for mains would come down very much indeed, even on my figures.

Mr. Addenbrooke.

But there is another way in which the cost begins to go up a little as you reduce copper sections. For instance, taking the cables quoted by a leading firm—their armoured concentric cables—I took out the cost of copper at an ordinary figure for each of those sizes of cable, and I took out the cost of insulation and everything else, and I found that if you had a conductor with something like a square inch section the figures came out practically exactly the same as those given by Mr. Callender; but when you came to a conductor 7/18, or something like that, the cost of insulation went up to over eight times the cost of copper. Therefore you see it is not all gain by adopting a high tension with small conductors: first, you have to pay an enormously higher proportionate figure for the insulation on the mains with the small conductors; and, as I pointed out in my paper, as the cost of insulating will probably come down in time, that is an additional factor for adopting direct supply.

But there is another point in which Mr. Geipel has not taken my paper rightly. I said distinctly, after calculating out the mains and bringing out the figure of £60 per kilowatt, that I do not consider this exactly a practical basis to argue on. It is true that that is the exact basis on which an alternating supply station would be run, and therefore I thought it as well to make the calculations so that they would cover both; but I go on to say that it seems to me extremely doubtful whether any central station where the feeders have to go any great distance, will be run in the future without accumulators at the feeder points. Mr. Geipel has spoken about losses in feeders and so on. There was a paper read before the North-East Coast Institution of Engineers about 15 months ago, by Mr. Alexander Siemens, containing a comparison of the running of the Willans and Bellis's engines, and it excited a great deal of comment at the time. It appeared in another form in Mr. Mark Robinson's paper before the Institution last year, and there was a good deal of discussion about it. But it has always seemed to me that the real gist of the paper—the great importance of it—has been entirely lost and forgotten, simply because it happened to contain a sort of exciting race between two engine makers. The real gist of Mr. Siemens's

paper, and what he wrote the paper for, has been lost sight of, owing to this splitting of hairs as to which engine was the best. Mr. Siemens's paper was written to show the running of the central station. It is true it is a central station established at their works, but, as most of you know, their works are very large. It is true the conductors are not so long as they would be for a central station, but to all intents and purposes they have a central station of about 1,000 or 1,200 H.P.; and that central station is working at a little less than nine hours' load—that is, a load-factor of 2·8, which is a great deal better than most central stations now, but a great deal worse than it would be if you ran all day. Messrs. Siemens show the results of a six months' run at that station under ordinary working conditions. The cost of their coal was 17s. 10d. per ton; they add the cost of labour and depreciation, and other matters. It is true that perhaps the labour may not be so large an item as it would be in an ordinary central station, because they have skilled engineers who can attend to it; still, they have put a figure down for it. The result is that with a load-factor of 2·8, and coal at 17s. 10d. per ton, their cost per kilowatt per hour came out at 0·58 of a penny. What Messrs. Siemens can do I suppose other people could do; that is to say, if you had a central station almost anywhere, you could, if you got even a nine hours' load, generate your current for something in the neighbourhood of ½d. per unit. Mr. Addenbrooke.

Mr. GEIPEL: Is it 0·28d. or ½d.?

Mr. ADDENBROOKE: It is ½d., I think. I will give the figures exactly afterwards: it is 0·58d. Now, supposing you have to charge accumulators from such a plant, and supposing those accumulators have 25 per cent. loss, you can see, allowing for that loss, the cost of the current comes to very little indeed; and, consequently, it appears to me that if we can introduce accumulators—which their present price admits of—we could supply the current, except for the question of distribution and one or two other questions, at a very much reduced figure than it costs at present. If we can get these 200- or 220-volt lamps, and we can cut down the cost of our mains in such proportion, and if we can get accumulators and keep our voltage even, we could get, to all

Mr. Addenbrooke. intents and purposes, quite as economical lamps as the 100-volt lamps in use at present, combined with the enormous gain derived from their use.

I think that, in reply to what some of the speakers have said, in view of the great gain to the companies by using 220-volt lamps, they could very well afford, where customers use 220-volt lamps, to make a reduction in the cost of the current; and I have shown that a reduction of one-third of a penny, or something like that, would really cover anything the consumer is likely to suffer from changing his voltage.

The President. The PRESIDENT: I have now a very agreeable duty to perform, viz., to move that the thanks of the Institution be accorded to Mr. Addenbrooke for his very valuable paper. If the discussion has been short, it has, at all events, been an interesting one; and that, no doubt, has been due to the matter Mr. Addenbrooke has brought before us.

The resolution was carried by acclamation.

The PRESIDENT: I have to announce that the scrutineers report the following candidates to have been duly elected this evening:—

Foreign Member:

Fritz Nial Wolff.

Associates:

Samuel Ernest Andrew.
Wellesley Curran Clinton.
A. H. Lidderdale.
Harold John Lintott.
Marshall Osborne.
Robert Cornelius Quin.
Henry John Rogers.

Students:

Alfred H. J. Graham.
Archibald Victor Mason.
William Edmund Miller.
John Robert Milnes.
Sidney A. Nash.
H. Ralph C. Partridge.
John M. Robb.
Reuben M. Sayers.
Frank S. Shaw.
Herbert Turnbull.
Robert N. Tweedy.
Charles Percy Walker.
Leonard Wilson.
Claude P. Wooler.

The meeting then adjourned.

The Two Hundred and Eighty-seventh Ordinary General Meeting of the Institution was held at the Institution of Civil Engineers, 25, Great George Street, Westminster, on Thursday evening, March 26th, 1896—Dr. JOHN HOPKINSON, F.R.S., President, in the Chair.

The minutes of the Ordinary General Meeting held on March 12th, 1896, were read and approved.

The names of new candidates for election into the Institution were announced and ordered to be suspended.

The following transfers were announced as having been approved by the Council:—

From the class of Associates to that of Members—

Philip Dawson.	William Charles Ullman.

From the class of Students to that of Associates—

Edward H. Cozens-Hardy.	Herbert Henry Gresswell.

Mr. Fairfax and Mr. Curra were appointed scrutineers of the ballot.

Donations to the Library were announced as having been received since the last meeting from the Board of Trade; Messrs. Biggs & Co.; the publishers of *Electricity;* Messrs. Griffin & Co.; and the India-Rubber, Gutta-Percha, &c., Co.; also from G. C. Maynard, Foreign Member; A. R. Bennett, Member; and J. Kingdon, Associate; to whom the thanks of the meeting were duly accorded.

The PRESIDENT: A copy of the balance-sheet having been forwarded to all Members and Associates some days ago, I suggest that it be taken as read.

This was agreed to.

The PRESIDENT: I will now move—"That the statement of "accounts and balance-sheet for the year ending December 31st "be adopted."

Mr. J. S. Raworth criticised the accounts and balance-sheet, which he contended did not contain sufficient information to render them intelligible in several respects; and he moved the following amendment, viz.:—"That the balance-sheet be referred "back to the Council for amendment."

Mr. W. M. Mordey seconded the amendment.

Mr. J. W. Biggs (of Messrs. Wagstaff Blundell, Biggs, & Co., the Accountants) having spoken in reply to Mr. Raworth's remarks, the amendment was put to the meeting and carried.

The following paper was then read:—

TELEPHONE EXCHANGES AND THEIR WORKING.

By Dane Sinclair, Member.

Mr. Sinclair. In introducing this subject I find that, to give you anything like a clear idea of the working of telephone exchanges as they exist in this country, it will be necessary for me to refer to a few fundamental principles underlying all telephone exchange work, which, however, have been previously explained in journals, text-books, and elsewhere.

In all telephone systems there are three branches into which they may naturally be divided, viz.—

(1) The line wires connecting subscribers' offices to exchanges;

(2) The instruments in subscribers' offices; and

(3) The switch-boards in the exchanges.

With reference to the lines, it is not my intention here to say much in regard to them; although, indeed, the lines now used for telephonic purposes differ very greatly from those formerly used for telegraphic work. It was not until the introduction of the telephone that such subjects as the static capacity and self-induction of lines received so much attention in other than submarine telegraph work. In telephone work, however, these points are of the very highest importance, and necessitate a large amount of attention. We have arrangements working on our telephone lines which, at first sight, would

have appeared to the old telegraph engineer to be the worst that Mr. Sinclair
could possibly be devised. I have made some experiments on telephone lines, and, under certain conditions, have obtained better speaking results over a line 40 miles in length, on which there was a series of earths, or leakages, than could have been obtained with a well-insulated line. The same applies to metallic circuits, but in this case the leakage is from the outgoing wire to the return. This subject, although interesting, is, however, outside the scope of my present paper.

Broadly speaking, all the calling instruments now used in this country in subscribers' offices are those known as the magneto pattern, and there is fitted along with each a transmitter, battery, and receiver, the whole forming a complete set.

It is, however, the switch-boards at the exchanges that I wish specially to bring before your notice to-night.

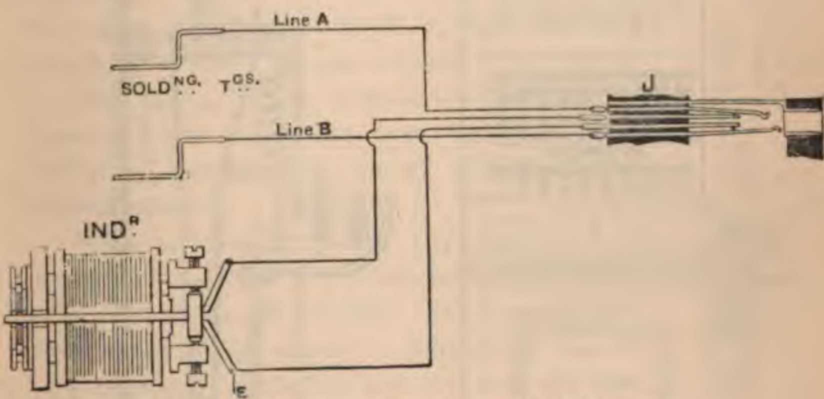


FIG. 1.—Line Connections of a Double Cord Board.

The diagram at Fig. 1 shows the connections which, with certain modifications, are made on all kinds of switch-boards. The apparatus includes a line jack, marked J, and an indicator, marked I, through both of which the circuit passes either to a general earth wire, or, in the case of metallic circuits, to a return wire. I may explain that what is called a "jack" is that part of the apparatus into which the connecting plug is inserted. When any two lines are to be connected together, two of these

Mr. Sinclair. plugs are inserted into the two jacks of the lines concerned, the plugs being connected together by a flexible conducting cord.

It is our usual practice in this country for small exchanges (of, say, under 200 lines) to make up the switch-board in sections of 50 lines. The drawing at Fig. 2 shows the type of

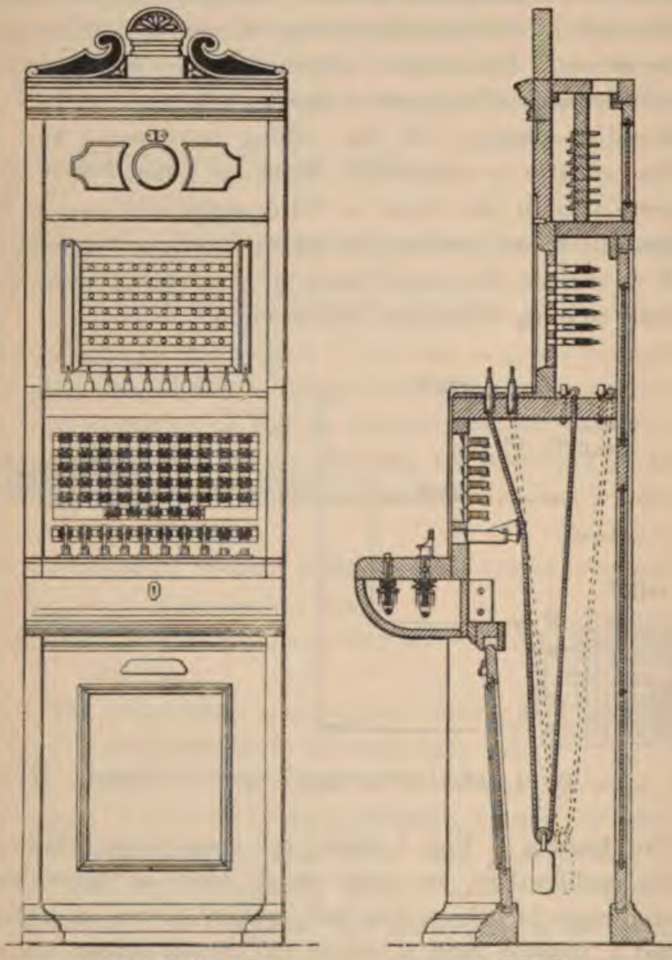


Fig. 2.—50-Line Switch-Board. Double-Cord Metallic Circuit

section which has been adopted by the National Telephone Company for general use in these small exchanges. In its main

principles it is the same as other small standard boards, but special attention has been given to the details; facilities have been provided for connecting the line wires to the switch-board, and all the working parts have been covered so as to exclude dust as much as possible. Mr. Sinclai

A further reference to Fig. 1 will show that here, as before described, the line passes through the jack and indicator, and back by the return wire. Cords, similar to the one already mentioned, are fitted on a shelf, each cord having a pulley and weight to bring it back to its proper place when out of use. A ring-off indicator is also provided, which can be put in bridge across the cord by means of the key designed for that purpose. This key is shown at Fig. 3, and by it the operator can also throw her telephone into or out of circuit as required. A separate pair of keys is provided to enable the operator to ring on either of the lines she is connecting. The ringing current is, as a rule, produced by a small generator driven by an electric or other motor. These listening keys and ringing keys are now universally used by the National Telephone Company, and are all of the standard patterns shown.

FIG. 3.
Listening Key.

When a subscriber turns the handle of his generator the shutter of his indicator in the exchange drops and shows his number. The operator then inserts one of the plugs of a double cord into the jack belonging to this line, and asks the subscriber what he wants. When this information is received, the operator inserts the plug at the other end of the cord into the jack of the line wanted, and completes the operation by turning the lever of her key, which cuts her telephone out of circuit and brings in the ring-off indicator. This indicator, as before mentioned, is now connected across the line in bridge in the case of metallic circuits, or tapped to earth in the case of single wires. This indicator is of a special type, being wound to a resistance of 1,000 ohms, and placed inside a tube of soft iron, so as to give it large self-induction

Mr. Sinclair. and cause great impedance to the passage of telephone currents, which are, of course, of high frequency. The object of this indicator is to show the operator when subscribers have finished their conversation. When this signal is given to the operator, the plugs are withdrawn and everything restored to its normal condition.

As the subscribers' indicators are cut out of circuit when their lines are connected as described above, they are of the ordinary type, and are wound to a resistance of 100 ohms.

In addition to the type of board already mentioned, shown at Fig. 2, we have used in this country very largely, for small exchanges and for private installations, a class of switch-board known as the "single-cord" board. In this pattern of board a cord and plug are provided for each line, and, as shown on the drawing

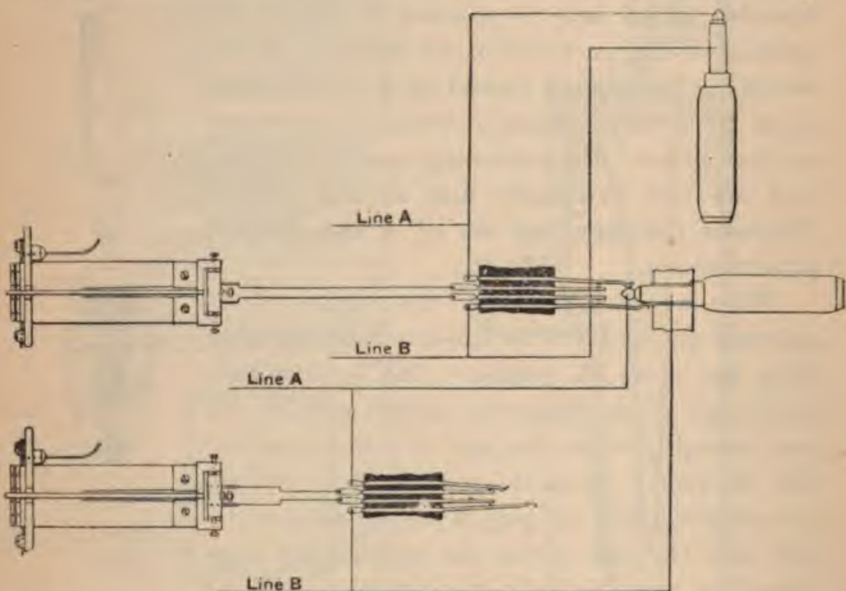


Fig. 4.—Line Connections of a Single-Cord Board.

(Fig. 4), the lines come to the outer springs of the jacks, and, without breaking, pass to the cord and terminate in the plug. In addition to this, a high-resistance indicator, of the same type as the ring-off indicator previously described, is provided for each line. To make

a connection, the plug of the line of the calling subscriber is Mr. Sinclair. inserted into the jack of the line wanted, leaving the indicator of the first line in circuit, and, as will be seen in Fig. 4, the indicator of the second line is cut out of circuit. For working this class of board, the operating instrument is provided with a plug for answering the calling subscriber and for ringing the subscriber wanted.

It will be readily understood from what has been said that, as exchanges increase in size, the switch-boards become too large for the operators to be able to reach to make all the connections. In the earlier days, wires were run between the various sections of the board for the purpose of connecting the different groups of subscribers' wires together. At this point commenced the difficulties of telephone exchange work, because there was no certain method of showing to the operators in the exchange when any subscriber's line was engaged, and also because the first operator had not complete control of the connection, and, consequently, it was liable to be interfered with by the second operator. In practice this became a very serious trouble. A remedy was found by our friends on the other side of the Atlantic, where they had to deal with the question of large exchanges earlier than we in this country. To overcome the difficulty they invented what is known as the "multiple" board, the possession of patents for which must have given the owners very considerable satisfaction, as well as yielded them enormous profits.

In this connection I may mention that the multiple system was independently invented by an *employé* of the United Telephone Company, but subsequently to the date of the American patent.

The multiple switch-boards used generally in this country are made up of the required number of sections, each containing all the apparatus necessary for 200 lines. Each section is 6 feet 6 inches in length, and is subdivided for four operators, each having 12 pairs of connecting cords, with the usual equipment of listening and ringing keys of the type shown at Figs. 3 and 5A. In addition to the full equipment of apparatus

Mr. Sinclair. necessary for 200 lines, each section is also fitted with jacks, through which all the lines in the exchange pass.

FIG. 5A.
Ringing Key.

On this principle the number of jacks necessary in an exchange increases in an amazing manner. For instance, an exchange with 400 subscribers' wires would require only 800 line jacks—*i.e.*, the 400 lines in the exchange would come to jacks on section No. 1, and be repeated on section No. 2; but, if we consider an exchange of 5,000 subscribers' lines under similar conditions, we find that there would be 25 sections of 200 lines each. As in the case of the two sections mentioned, the line jacks would be repeated on each of the 25 sections (5,000 on each), making a total of 125,000 line jacks. In practice every exchange is provided also with junction wires to other exchanges, and many of them with trunk wires to other towns.

The junction wires are divided into two approximately equal groups, one carrying the outgoing and the other the incoming traffic. To render the outgoing junctions accessible to all the operators, they are, like the subscribers' lines, multipled on every section. Incoming junctions do not require to be multipled, but special sections are provided for working them, and these also contain a multiple of all the subscribers' lines. As it is found in practice that an operator cannot attend to more than 25 of these junction lines, each section, with four operators, will accommodate 100 junction lines.

In an exchange of 5,000 subscribers, forming part of a system similar to that existing in London, there would be 1,000 junction wires, say 500 outgoing and 500 incoming. The latter would necessitate the provision of five extra sections, thus bringing the total to 30 sections, whilst the former would involve the use of 500 additional jacks on each section, making the total number of jacks 165,000.

It will thus be seen that a multiple board for 5,000 subscribers' lines is a huge electrical equipment. The number of soldered joints on such a switch-board, in connection with the jacks alone,

is nearly a million, and the total length of wire is between 1,500 and 1,600 miles. Mr. Sinclair

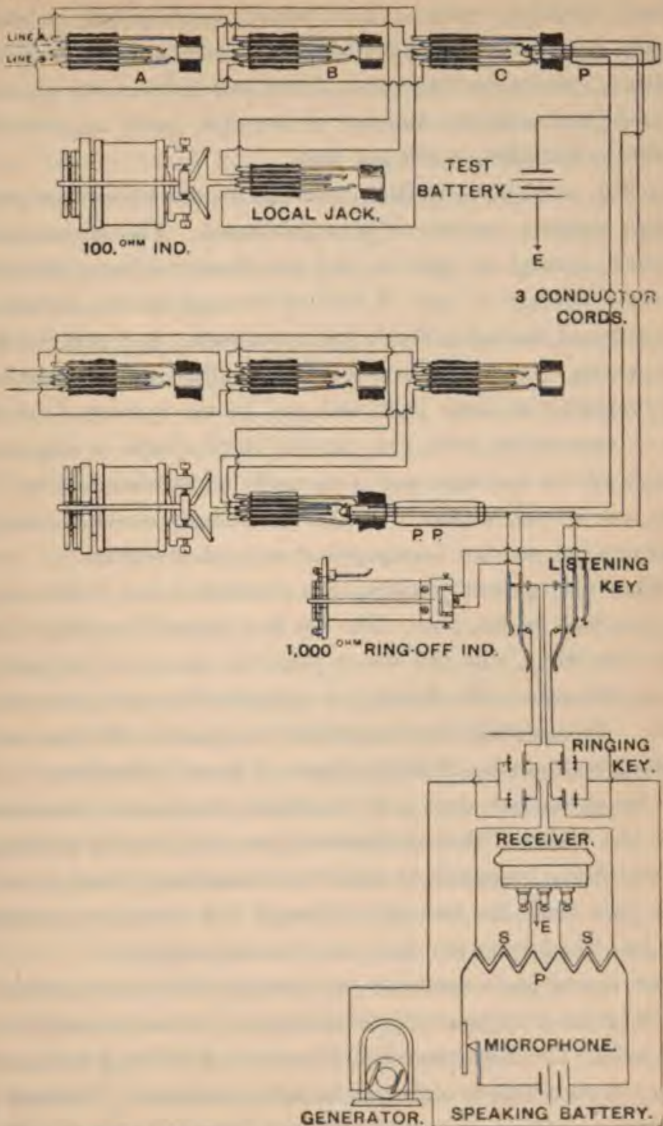


Fig. 5.—Multiple-Board Connections, with 5-point break jacks, showing subscribers joined together by plugs P and PP.

The largest switch-board we have in this country is one which has been provided for taking the total number of jacks required

Mr. Sinclair. for 8,400 subscribers' lines—*i.e.*, including junctions, 9,000 line jacks on each section—and for such an exchange, fitted on the ordinary multiple system, there would be required a total of 432,000 line jacks; so that, while we have only increased the number of subscribers' lines from 5,000 to 8,400 (*i.e.*, 68 per cent.), we have increased the number of multiple jacks required from 165,000 to 432,000, or 162 per cent.

In Fig. 5, A, B, C, D, &c., represent a subscriber's line passing through separate sections of a switch-board. The wires come to the outer springs of jack A, and pass from the inner contacts to the outer springs of jack B, and so through all the sections. If the number of this subscriber's line is between 1 and 200, the wires, after passing through all the sections, would return to section A, pass through the local jack, and end in the indicator. A third wire in connection with the barrels of the jacks is also carried through all the sections, and is normally an insulated wire. This is the test wire by means of which an operator ascertains whether or not the line wanted is engaged at any other section.

When an operator replies to a subscriber she inserts a plug into the jack of his line. The tip and ring of the plug connect to the line wires, and the sleeve joins the barrel of the jack to a battery, the other side of which is connected to earth or a common return. To complete the connection the jack of the line wanted is similarly treated. Should either of these subscribers now be asked for at another section of the board, the operator there would touch the barrel of that subscriber's jack with the tip of the plug with which she proposed to make the connection, when a current would pass from the test wire through her telephone, causing a click, and so advising her that the line was engaged.

The spring jacks are made up in strips of 20, mounted on two parallel pieces of vulcanite 1⅜ inches apart I submit a sample strip of these jacks. The front piece is 11½ inches × ½ inch × ½ inch, and the distance from centre to centre of the jacks is ½ an inch. The back part is slotted, and the springs which fit into these slots are shouldered, so that they cannot be forced out of position by the plug. Each jack has two long springs to which the line wires are connected, and these grip the plug. These springs rest on shorter

springs (both being provided with platinum contacts) which Mr. Sinclair are connected to the corresponding jacks in the succeeding sections of the board, and, lastly, to the local jack and indicator. A strip of metal is connected to the barrel of the jack and is carried to the back as a soldering tag, and to this the test wire is attached. These strips are secured to stiles in the upper portion of the board by special fasteners which allow of any strip being readily withdrawn for repairing purposes.

I have here a sample showing how one row of jacks is connected by cable with the corresponding row in the succeeding section of the multiple.

The wires are carried throughout the switch-board in 63-wire cables, each cable serving 20 subscribers or one strip of jacks, and having three spare wires to provide for breakages. The copper conductor is No. 22 gauge, insulated with rubber and paraffined cotton. The wires are laid up in threes—two line wires and one test wire for each subscriber. Seven such strands are twisted together, and three such groups of wires are laid side by side and covered with cotton braiding saturated with paraffin. The size of the finished cable is about $\frac{7}{8}$ inch $\times$ $\frac{3}{8}$ inch.

The listening and ringing keys, and their connections, are the same as those shown with reference to small boards.

The operator's telephone has received considerable attention of late years. It was, until lately, the practice to suspend the transmitter from the top of the board, and the receiver had to be held to the ear by hand. Now the transmitter is fitted in an aluminium case, which is fixed to a light breast-plate of the same metal, and this is suspended round the neck of the operator, so that the mouth-piece is always conveniently placed for talking into The receiver is also made up in a light form, and kept against the operator's ear by metallic springs or an elastic band. By the use of these instruments both her hands are left free for operating. The induction coil of the transmitter and the coils of the receiver are differentially wound, and the centre point of the latter coils is joined to earth to allow of the "engaged" test being obtained, and of the operator working earth circuit and

Mr. Sinclair. metallic circuit lines on the same board indiscriminately. The earth being connected to the centre of the differentially wound coil has no detrimental effect on a metallic circuit line.

Fig. 7.—View of Operator, showing Breast-Plate, Microphone, and Receiver.

The boards just described are complete metallic circuit boards, and are used very extensively in this country. They work satisfactorily on earth circuits, and, if necessary, may be employed on earth-circuit systems as transition boards. When on this system metallic circuits are joined to other metallic circuits they form a perfect metallic loop, but when joined to earth circuits one side of the metallic circuit is earthed at the exchange; the circuit so formed being but little better than a line with earth return throughout, the second line simply acting as a screen to lessen induction. All these connections are made in an exactly similar manner, the operator not having to distinguish between single and metallic circuits.

The problems in switch-board work have always been, firstly, How quickly can a connection be made? and, secondly, How can efficiency be best obtained? Mr. Sinclair

With reference to the first, the desired end is attained by reducing to a minimum the number of movements necessary, and making those movements as easy as possible.

With reference to the second condition, in the earlier boards it was usual to leave the two line indicators in circuit when the lines were joined together; and the first step taken to improve this was to cut one out, or to cut out both line indicators, substituting a special indicator for the purpose of receiving the subscriber's clearing signal. The electro-magnet of this indicator was, however, directly in the circuit. It was observed that any such electro-magnet in the line circuit cut down the talking very considerably, one indicator having probably as much effect in reducing the efficiency of the speaking as 50 miles of an ordinary aerial line. The next step was to increase the resistance and self-induction of the ring-off indicator, and place it in shunt across the two lines of a metallic circuit, or as a tap to earth on single lines. It had also been found that trouble was sometimes caused by dirty contacts in the spring jacks. To obviate this difficulty some of the later boards have all the spring jacks wired in parallel, and the two line indicators, which are of special pattern, left in shunt. This system is sometimes called the "self-restoring" and sometimes the "branching" system; but, as the latter name had been correctly applied to other systems which had preceded it, and of which this is an extension, I prefer to use the former term

In this system the work of the operator is lessened, inasmuch as the shutter of the indicator is automatically restored in answering the subscriber. This allows the indicators to be placed at the top of the boards, where space is not so valuable, and the spring jacks to be placed lower, thus bringing a much larger number within easy reach of the operator, and materially increasing the ultimate capacity of the board. The general arrangement of this class of board is much the same as that previously described, except that, as just mentioned, the indicators are placed over instead of under the spring jacks. The apparatus, however, is

Mr. Sinclair. somewhat different. The springs of the jacks are let into a solid slab of vulcanite. There are three of these springs, two being of equal length, and one shorter. The front of the slab of vulcanite carries two bushes, one behind, but insulated from, the other. The line wires are continuous throughout the exchange, ending at the subscriber's indicator. Branches are brought from these at

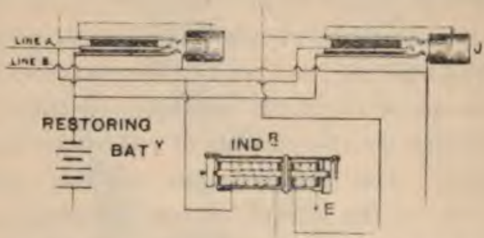


FIG. 68.—Diagram of Branching System with Self-Restoring Indicators.

each section, one to the short spring, and the other to the inner bush of the jack. The two springs of equal length are joined, one to a common battery wire running round the exchange, and the other to the corresponding springs of all the jacks in the same line, and, finally, also to the indicator. This latter spring is also in metallic contact with the front bush of its own jack. When a plug is inserted in a jack, the tip comes into contact with one line through the short spring; the sleeve, through the barrel, with the other line; and the two springs of equal length are connected by an insulated metallic ring between the tip and the sleeve. The tip and the sleeve are joined to the two conductors in the flexible cord used for connecting two subscribers.

The indicator consists of two separate single-coil electromagnets, both sheathed with iron, and fixed one in front of the other. To the back one, which has a resistance of 1,000 ohms, the line wires are attached. The front one, which has a resistance of 45 ohms, is connected on one side to the test circuit, and on the other to earth or to the common return of the restoring battery.

When a subscriber calls, a heavy armature pivoted in front of the restoring coil is released, and, falling forward a short distance, lifts a light aluminium shutter, disclosing the subscriber's

number. When the operator inserts the plug to answer the Mr. Sinclair subscriber, the heavy armature is drawn backward and held fast

FIG. 3A.—S. Rg. Indicator.

in its normal position so long as the plug remains in the jack. The aluminium shutter, of course, resumes its normal position at the same time.

As before explained, the front bush of each jack is connected to this restoring circuit, and the connections of the operator's instrument are so arranged that, when she touches this bush with the tip of one of her plugs, part of the current is shunted through her receiver, showing her that the line is engaged. As one of the connections is dependent upon the contact between the inside of the bush and the sleeve of the plug, which must fit somewhat loosely, the plug is provided with what we call "umbrella" springs. The ring-off indicators are of the same pattern as those above described, but are so arranged in connection with the listening keys that when the operator's instrument is in circuit the indicator is locked, but is free to respond to the subscriber's ring-off current, when, by pushing the lever forward, this instrument is cut out of circuit.

This class of board with self-restoring indicators is being introduced into London at the same time as the subscribers' lines are being metallic-circuited, and this work will be entirely finished in a few months. One of the principal exchanges fitted with this class of board is that at Lime Street, City.

It is to be noted that, as these self-restoring indicators require permanent current to keep them locked while the lines are in use, special arrangements have to be made at each exchange for providing this current. As a typical case, I may mention that at Lime Street the current is supplied by 12 E.P.S. cells of 23 L type, charged by an Elwell-Parker dynamo running at 800 revolutions and giving an output of 45 amperes at 15 volts. This dynamo is driven by a Tangye gas engine of 1 H.P. nominal. The engine also drives the generators which supply the ringing

Mr. Sinclair. current. One-half of the cells—*i.e.*, 6—are in use at one time, arranged in three groups of two each; and each group supplies

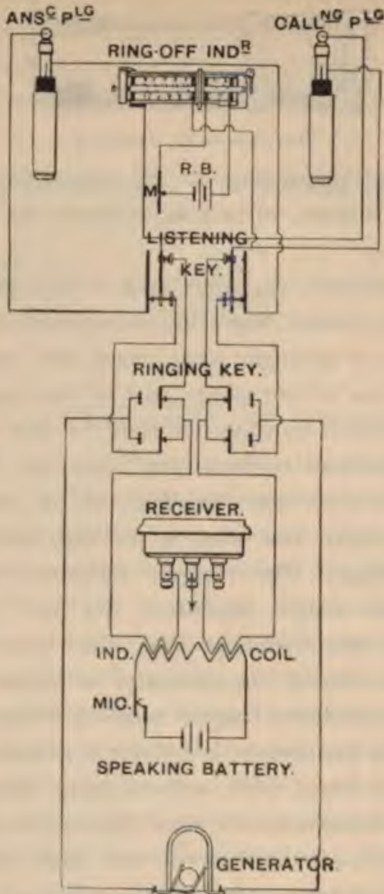


FIG. 6A.—Diagram of Branching System with Self-Restoring Indicators.

current for one-third of the whole exchange—*i.e.*, about 1,300 indicators. The current for the operator's transmitters is supplied by a similar number of cells divided in the same way. In this case each group supplies current for about 30 transmitters. To prevent overhearing it is found essential that the circuit of each transmitter should be taken separately by direct leads from the terminals of the batteries. A duplicate set of cells is provided, and one set is being charged whilst the other is in use.

From what has previously been said as to the number of jacks required for an exchange with 5,000 subscribers' lines, and the increased proportion in the number required when the exchange is fitted for 8,400 lines, it is evident that, apart from cost, the question is a very serious one; indeed, it becomes so serious that while on every hand it is acknowledged—and I think rightly acknowledged—that the multiple system is the best, a point may be reached where the vast number of jacks and large quantity of cables used introduce troubles almost equal to those previously overcome by the use of the multiple board. In America they are trying to meet the difficulty to some extent by the introduction of what is known as the "divided multiple" board, whilst I have endeavoured to meet it by the use of flat boards. The weak feature of the divided board is that no connection is made without being dealt with by two operators, and, consequently, the chief advantage of the multiple system—viz., that the operator who receives a call completes the connection—is lost. But with the flat board, fitted as I shall presently describe, this advantage is retained, whilst, broadly speaking, one-half only of the line jacks and cable are needed. Mr. Sinclair.

It is about eight years since I commenced the use of flat boards, when a small one was fitted at Paisley. The working of this board proved that the flat board as a system, if fitted with the proper material, could be worked very successfully. I am aware that flat boards had been tried in this country before that date, and that some were in use in America; but, so far as I can learn, the number of jacks used was not less than that on the ordinary upright board. I therefore cannot see the reason for introducing them, unless, indeed, it was considered they were better flat than upright from an operating point of view. I am aware that there are in this and in other countries telephone engineers of the highest reputation who are not at one with me on the question of the advisability of introducing flat boards; but, after the fullest and most mature consideration, and experience of their working for several years, I see no reason why they should not be used largely under certain conditions. When flat boards are fitted up in comparatively small exchanges, the saving

Mr. Sinclair. on the jacks and cable is not equivalent to the extra expense of the framework, and therefore I do not recommend their use for small exchanges. But for large exchanges with from 2,000 to 8,000 subscribers' lines there is in my mind no doubt that this is the best class of board to use.

The principal reasons for this opinion are—

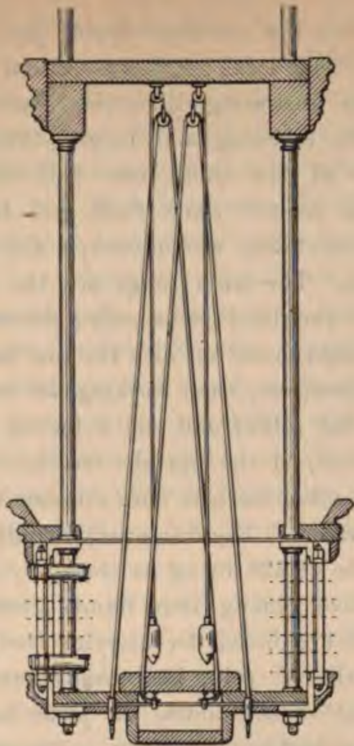
1. That, in consequence of the smaller number of jacks and quantity of cable used, better speaking results are obtained, and fewer faults occur. I have only to point out to you, as electrical engineers, that for an 8,000-line exchange the number of soldered connections is reduced in the flat, as compared with the ordinary upright board, by over half a million, to bring this point of efficiency forcibly before you.

2. In many cities it is very difficult to find switch-rooms large enough to take from 5,000 to 8,000 subscribers' lines; but with the flat-board system this difficulty does not exist to the same extent, as practically they take only half the floor space required for upright boards.

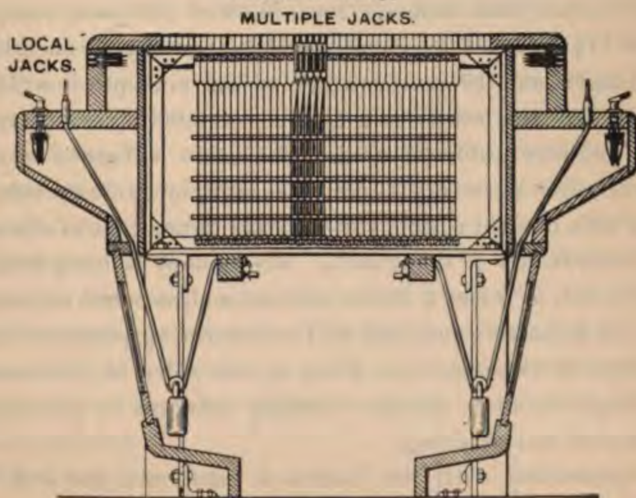
There are likewise the questions of the cost of the boards, rent of switch-rooms, lighting, heating, &c., which bear some proportion to the space occupied; but these are secondary considerations, the principal one being efficiency.

I should like to make it perfectly clear that, while I consider flat boards the right pattern to use under certain conditions, I do not recommend their use in all circumstances. With self-restoring indicators, which do not require to be within reach of the operator, and may consequently be placed overhead, and the jacks for use with which have no breaking contacts, with the consequent trouble arising from dust, I consider them the right class of board to use. I also consider the flat board the best to use in connection with exchanges of all sizes worked on the call-wire system.

Fig. 6 shows a section of the type of flat board with self-restoring indicator before referred to. It will be seen that when a plug is inserted into a jack the springs of the jack do not break any connection, and when the plug is withdrawn there is no contact point to be restored.



Section of Canopy.



Section of Table.

FIG 6.—Flat Board with Self-Restoring Indicators.

Sinclair. The table carries the multiple spring jacks, the barrels all facing upwards. The local, or home-section, jacks, which are always used when answering subscribers, are at the side on the upright. The listening and ringing keys are fixed on a shelf at the side of the table, one half of the cords and plugs being fitted on the same shelf, and the other half in a canopy above the table, which canopy also carries the self-restoring indicators. The lower plugs are the answering plugs, and are inserted in the local jacks only; the overhead plugs are used only for making connection with the line jacks on the top of the table. The operators, each working 50 subscribers, sit on both sides of the flat table; and the 6 feet 6 inches section of multiple jacks, which, on the upright board, is common to four operators with 200 subscribers, is here common to eight operators working 400 subscribers. The framework is built of T and L iron faced with wood, the details being as shown by sectional drawing at Fig. 6. Vertical oblong iron frames cross the tables at regular intervals of 11½ inches for carrying the jacks and cables. The ends of the strips of spring jacks rest on and are fastened to the upper edge of these frames, the jacks being placed in a vertical instead of a horizontal position. The cables are carried by racks inside these frames. Each block of 100 jacks occupies a space of 11½ inches × 2½ inches; and as there are six such blocks in the length, and 10 in the width of the multiple, it will be at once seen that the board has a capacity of 6,000 lines. A special type of 63-wire cable is used. The cable is formed of seven groups of three strands of three wires each, laid side by side, and covered with braided cotton, the external dimensions of the cable being 1·312 inches × 0·260 inch. The canopy is hung from the ceiling by rods at 3 feet 3 inches centres, and, as before mentioned, carries the indicators and half of the connecting plugs and cords. The strips of indicators are fixed in the sides of this canopy, being hinged to allow of their opening outwards for convenience of inspection and repairing.

In connection with flat boards I mentioned the call wire, and this introduces us to a system of working telephone exchanges differing largely from any I have previously described.

The use of this system has been very much discussed by telephone experts. In the call-wire system each subscriber has, in addition to his direct line to the exchange, the use, in common with a number of other subscribers, of a wire known as the "call wire," which, starting from the exchange, is branched into the offices of, say, 50 subscribers. On this call wire, the operator attending the subscribers is continuously listening in the exchange. The subscriber's instrument is fitted with a switch which enables him to place it in connection with the call wire, on which he asks for the subscribers he requires. These, of course, are connected on his direct wire, and are rung up by him, the operator not interfering with the connections until told on the call wire to clear. It will be seen from this that, when a subscriber takes a long time to answer his bell (and there are many of them who do so, especially in London), he has to explain to the calling subscriber the reason of the delay, which would, in all probability, have been otherwise attributed to the operator. There being 50 subscribers connected to the telephone of each listening operator, it is evident that any number of them may try to speak at the same time; but here, as in all matters of business, common sense, as a rule, prevails, and a subscriber coming on to the call wire and hearing others talking to the operator does as he would do if booking a ticket at a railway office—*i.e.*, takes his proper turn—and so the calling is done without confusion and more quickly than with the indicator system. It must be clear to everyone who considers the matter that an operator cannot attend to two subscribers at the same time; and, generally, it is quite as satisfactory to a subscriber to listen until he hears that the operator is free, as to ring time after time until the operator is able to attend to his call. It must be obvious, however, that the number of subscribers a call wire will accommodate is limited, and, as hereafter explained, great confusion would arise from overloading it.

I have before now been accused of something like inconsistency in advising in favour of this system in some places, and against it in others. In deciding upon any particular case the local

r. Sinclair circumstances have to be taken into consideration, and, after a careful study of the subject, the decision I have arrived at is that, given a town where all, or nearly all, the subscribers' lines terminate in one exchange, there is no doubt that the call wire gives the most perfect service. For this reason we have introduced the call wire into Glasgow and nearly all the towns in Scotland. We are also introducing it into Manchester. It would, however, be absolutely unworkable in London. The full explanation of this would take more time than can be given to it in a paper of this kind; but, broadly, it may be said that in a great city like London, where there are a large number of exchanges, and consequently the subscribers' lines terminate at a number of different centres, the call wire becomes unsuitable. Let us take an instance. Suppose a subscriber on our King's Cross exchange, whose office has been fitted with the call wire, wishes to communicate with a subscriber on Lime Street exchange, in the City, he presses his call-wire key and gives the listening operator the number of the subscriber he requires. The operator has then to do one of two things: she has either to cut herself off from the local call wire, in which case the main feature of the call wire, viz., continuous listening, is sacrificed; or to connect her telephone, as well as the call wire with its 50 subscribers, on to a call wire to the City. Other operators in the same exchange may have been asked by their subscribers for subscribers in the City, and may also have connected their call wires to the same City wire. In the event of a connection having to be made through two or three exchanges this trouble would be increased, and it would often be found that operating would be rendered impossible, owing to the large number of subscribers connected together all clamouring for their instructions to be taken first. The effect would be somewhat similar to that of a crowd of people attempting to rush out of a public building, on an alarm of fire, through a doorway too small to accommodate them; they simply get jammed in the doorway, with the unhappy result that they perish in the attempt. In the same way the subscriber at King's Cross might stand at his instrument and perish before he succeeded in getting through to the subscriber in the City. With this explanation it will, I am

sure, be apparent to everyone who thoroughly studies the matter how it is that the call wire may be successful at one centre where all, or nearly all, the subscribers' lines are grouped in one exchange, and be a complete failure if introduced into an exchange system like that of London. Mr. Sinclair.

All things being considered, we find that the call wire gives more satisfaction than the indicator system, and it is perhaps to be regretted that it cannot be introduced under all circumstances. We had the indicator system with multiple boards at work for many years at Glasgow, and we changed to the call-wire system. Nine months after the introduction of the new system the subscribers were asked whether they preferred the call-wire or the indicator system previously in use, with the result that 95 per cent. of the subscribers were in favour of the new system; and it was this result that decided the question in favour of its introduction into Manchester.

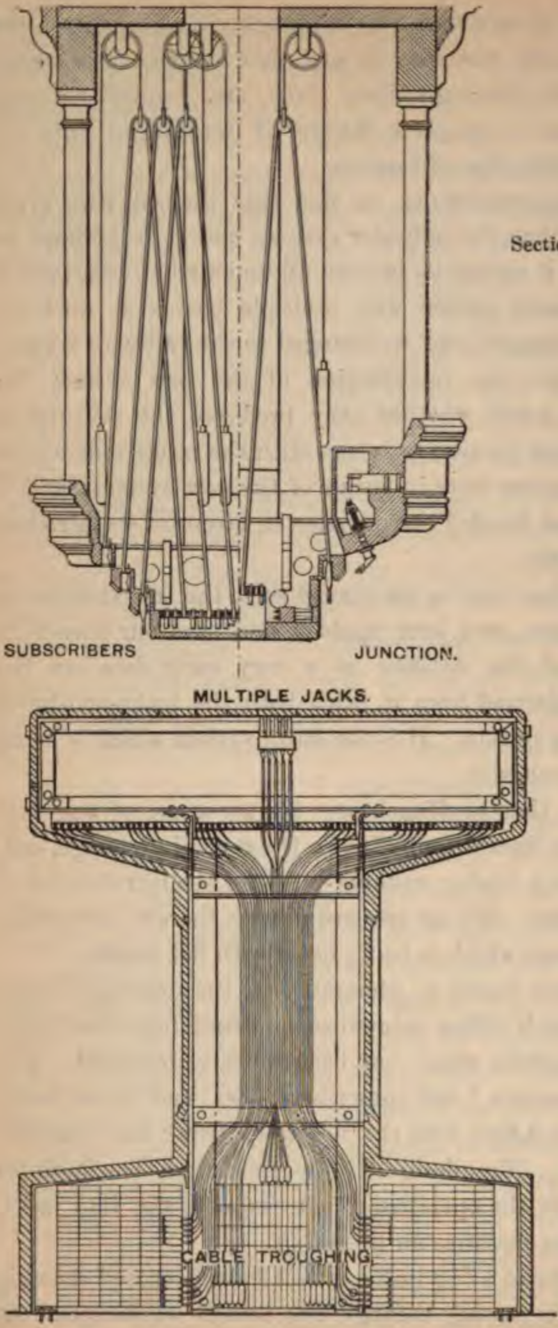
The call wire has been in use almost since the introduction of telephone exchanges, and here again I find that our friends on the other side of the Atlantic at a very early date saw the advantages to be derived from it, with both the make-and-break and the branching system. It is the latter system which is being introduced at Manchester.

It so happens that at Manchester 90 per cent. of our subscribers have their lines terminating in the central exchange, and, consequently, it is a highly suitable place for the introduction of the call-wire system. We are now installing it there in connection with a new exchange which is being fitted with flat boards.

The Manchester board is illustrated in the drawing Fig. 8. It will be seen that it differs somewhat in detail from that with self-restoring indicators which has been already described. The board will accommodate 7,200 subscribers' lines, and is now being fitted complete for 4,800, with the necessary trunk and junction wires in addition. The design of the framework has been so modified as to allow the operators to get nearer to the line jacks, which gives greater facilities for operating.

I may now refer to a few load curves I have prepared showing the number of calls passing through our busiest exchanges. At

Mr. Sinclair.



Section of Canopy.

Fig. 8.—Manchester Board.

Section of Table.

the top of these we find Liverpool, where the average number Mr. Sinclair of calls per subscriber per day amounts to 18·6. The pressure of

FIG. 9.—Diagram showing Originating Calls. Upper Curve: Liverpool.

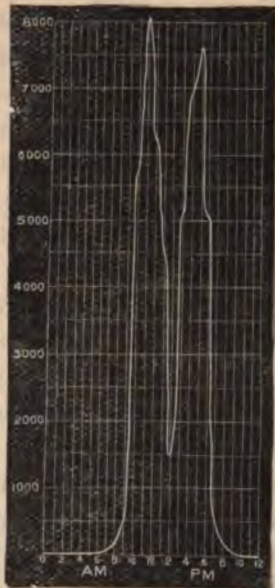


FIG. 10.—Curve showing Calls at Manchester Central Exchange for one day.

the work will, however, be better understood by noticing that at certain hours of the day the number of calls is very high. For instance, between 4 p.m. and 5 p.m. the average is 11,050. I believe this is a higher average than is to be found in any other exchange in this or any other country in an exchange of this size.

An important part of an exchange system in a place like London is the proper arrangement and working of the junction wires between the different exchanges. I have found that the best way to arrange these is to have, in addition to the direct wires, a central junction-wire exchange, between which and every other exchange two or more wires are provided. It will be readily

Mr. Sinclair understood that in a system like that of London, where there are 37 exchanges, it would be impracticable to run from each new exchange opened in the suburbs direct wires to all the others. Therefore the central junction exchange becomes a necessity. It is obvious, however, that such a central exchange must introduce extra operating, and consequent delay, into the service; and, therefore, where we have as many as 60 or 70 messages per day between any two exchanges, we provide two direct junction wires. Beyond this, an additional junction wire is provided for each 40 messages per day. Taking the average duration of each call as three minutes, it will easily be seen that, to meet the maximum pressure at the busiest time of the day, so many junction wires have to be provided that the average time each is in use amounts to only two hours out of the 24.

The President. The PRESIDENT: Gentlemen,—It is now my very agreeable duty to propose that our best thanks be accorded to Mr. Sinclair for his very interesting paper. We seldom have papers on subjects connected with the telephone, and I wish we had more. It is particularly gratifying when we do have one that it should be by a man of Mr. Sinclair's ability, and one who holds such an eminently responsible position with regard to the telephone business in this country. After the applause with which you received Mr. Sinclair's paper, it seems scarcely necessary for me to put to you the motion I have made; but, as a matter of form, I move that our best thanks be accorded to Mr. Sinclair for the very able and interesting paper read by him this evening.

The motion was carried by acclamation.

The PRESIDENT: I am afraid we have not time for even one speaker this evening, so that we shall be obliged to adjourn the discussion until our next meeting.

The PRESIDENT announced that the scrutineers reported the following candidates to have been duly elected:—

Members:

Thomas Topham Hardaker. | R. W. Weightman.

Associates:

Gabriel Andreoli.
Captain Mossom Archibald Boyd, R.E.
Ernest James Cochrane.
Philip Henry Dawe.
Léon Gaster.
Harold Hastings.
Samuel Thomas Pemberton.
Edward Gould Tillyer.
William Robt. Clapcott Wakley.

Students:

John Arthur Hotham Clifford.
H. F. Hesse.
Reginald Wilson Gauntlett.

The meeting then adjourned.

ABSTRACTS.

F. ROEVER—THE ELECTRIC ENDOSMOSE OF TANNIC ACID SOLUTIONS THROUGH HIDE DIAPHRAGMS.

(*Wiedemann's Annalen, Vol. 57, No. 2, p. 397.*)

The author measured the amount of tannic acid solution which was forced through hide by an electric current, the hide being in the condition in which it is found in the tannery. The tannic acid solutions used were 0·3–0·5 per cent. solutions of quebracho extract in clean water.

A piece of unhaired cow-hide was freed from lime by means of cresotinic acid, and pressed between two horizontal glass plates having central apertures of 1·5 cm. diameter, the hair or grain side of the hide being uppermost. The glass plates were cemented together at the edges by means of sealing wax. On the upper glass plate was cemented a glass bell of 2·5 cm. diameter, in the neck of which a capillary tube of 1·04 mm. diameter was mounted by means of a cork, a millimetre scale being arranged against the capillary tube. The lower square glass plate rested on two glass strips in a flat glass tray, which, with the bell, was filled with a 0·2 per cent. solution of tannic acid, all air bubbles beneath the hide and in the bell being carefully removed. The electrodes consisted of two platinum plates in the tray and in the bell, the platinum wire of the electrode being fused into the wall of the bell.

The current from 20–80 accumulators of 2·25 volts E.M.F., arranged in series, passed through a reversing switch and mirror galvanometer (1 scale-division = 0·000111 ampere), through one electrode, the tannic acid solution, and through the hide exposed between the apertures in the glass plates to the other electrode. When the current was not passing, the position of the meniscus in the capillary tube did not sensibly vary. When the circuit was closed, the tannic acid solution was forced from the positive electrode through the hide to the negative electrode, and the time measured which the meniscus, in the capillary tube of the bell, took to rise or fall 10 mm.

Since the capillary tube had a cross-sectional area of 0·855 sq. mm., the current had consequently transferred 0·00855 grammes of fluid through a circular area of 1·5 cm. diameter (or 1·767 sq. cm.) of the hide in z seconds.

The experiments showed that z was approximately inversely proportional to the electro-motive force, E, of the battery. It was found to be almost immaterial whether the current passed upwards or downwards through the hide.

If P be the quantity of the fluid forced through O sq. cm. of the hide by an E.M.F. of E volts in z seconds, we have

$$P g = C . E . O . z.$$

The experiments with a 0·2 per cent. solution of tannic acid are given in the following table; E being the E.M.F. of the accumulators in volts, z the time in which the meniscus in the capillary tube rose or fell 10 mm., C the quantity in

grammes of fluid forced through 1 sq. cm. of the surface of the hide in a second by an E.M.F. of 1 volt, J the current in amperes, and W the resistance expressed in ohms of the circuit or of the piece of hide :—

E.	z.	C × 10⁶.	J.	W × 10³.
180	13·50	1·999	0·00756	23·81
135	17·30	2·066	0·00612	22·07
90	26·15	2·056	0·00367	24·52
45	51·85	2·074	0·00222	20·23
	Mean ...	2·049	Mean ..	22·66

For a 0·2 per cent. tannic acid solution the quantity of liquid forced through 1 sq. cm. surface of the hide in one second by means of an E.M.F. of 1 volt is

$$C = 0·000002048 \text{ grammes.}$$

The resistance of the piece of hide of 1·767 sq. cm. surface is about 22,660 ohms; for a similar piece of 1 sq. m. area, 1,282 ohms. An E.M.F. of 100 volts would therefore force 7·377 kilogrammes of tan liquor in an hour through 1 sq. m. area of similar hide.

The current-strength increased rapidly on closing the circuit, until a maximum had been reached after 0·2–8 minutes. Then the current began to gradually decrease, to again increase on reversing the current. The maximum current was reached sooner, accordingly as the intervals between the reversals were made shorter. Since the strength of the current increased to a maximum after the reversal, and then decreased again, the reduction of the strength of the current could not have been caused by internal polarisation of the porous hide, but rather by an alteration in the electrical resistance. The increase of resistance appears to be attributable to a closing of the pores of the hide, since the amount of liquid passed through decreased as the resistance increased.

As an example of this variation of resistance, the following are given as the results obtained with a 0·3 per cent. tannic acid solution and 180 volts E.M.F.; the arrows showing the direction of the current in the hide, and *s* the deflection of the galvanometer needle in scale-divisions:—

Time	0 min.	2	4	4·2	6	8	9	12 min.
s	79 mm.	92	83·5	88	84	82	96·5	85 s.-div.

Current reversed 8 times.

Time	23·2 min.	24	25	34	37	38	44 min.
s	97 mm.	83	98	63	79	80	71·5 s.-div.

SUMMARY.

1. 0·2, 0·3, and 0·5 per cent. solutions of tannic acid were only slightly forced through the hide by the hydrostatic pressure, but were carried through in considerable quantity by the electric current. The liquid was moved in the same direction as the current.

2. The effect in the first minute is proportional to the E.M.F. applied, but is not proportional to the current-strength.

3. The quantity of liquid transferred and the current-strength decrease after the current has passed for 0·2–8 minutes in the same direction.

4. On reversal, the current increases to a maximum in 0·2–8 minutes, and then decreases again.

5. In order to promote the circulation of the tan liquor in the pores of the hide by the electric current, the current should be reversed at short intervals—say every minute.

SIEMENS and HALSKE—NOTE ON THE PRODUCTION OF RÖNTGEN RAYS.

(Elektrotechnische Zeitschrift, Vol. 17, No. 7, p. 105.)

This research was made with the object of discovering whether more advantageous means could be found for operating Crookes tubes than the usual Rhumkorff coil, so as to prevent the frequent failure of the tubes due to irregular action of the interruptor, and to enable a number of tubes to be worked simultaneously.

It was found that the apparatus in use by Messrs. Siemens & Halske for working their well-known "ozone tubes" (see *Elek. Tech. Zeit.*, 1891, p. 342) was very suitable; the special features of this apparatus being the employment of comparatively low potential differences (about 10,000 volts), and rapid and regular alternations of the current in the primary circuit.

Through the primary circuit of this apparatus was passed either an interrupted unidirectional current, by using a rotary interruptor, or an alternating current of as high a frequency as possible.

By these two means—preferably the first mentioned—a continuous phosphorescence was produced in the glass wall of the tube, and the well-known photographic effects obtained thereby, although the character of the light was different to that produced by the means usually employed. Moreover, several tubes could be worked simultaneously even by the smallest apparatus. The time of exposure of the photographic plates, when using a single tube, did not appear to be materially shorter than with the ordinary apparatus. The bursting of the tubes is, however, almost entirely prevented.

Similar results to those obtained with Crookes tubes were also produced with ordinary incandescent lamps in which one pole of the generator was connected to the carbon filament, and the other pole to a piece of tin-foil arranged opposite thereto on the outside of the glass.

H. ABRAHAM and J. LEMOINE—ON THE MEASUREMENT OF VERY HIGH POTENTIAL DIFFERENCES.

(Journal de Physique, 3 Ser., 4, p. 466–471; Beiblätter, Vol. 20, No. 2, p. 136.)

In order to maintain a constant potential for testing the sensibility of an electrometer, the authors used the following arrangement:—The electrical machine was maintained in rotation at an uniform velocity by means of a small electro-motor producing a permanent discharge between the poles, which were provided with balls. One pole was connected to earth, and the other to the inner coating of a jar by means of a conductor insulated with paraffin, the outer coating of the jar being connected to earth. The inner coating of the jar then showed a very nearly constant potential, which only varied between 19,970 *v* and 19,990 *v* during an experiment lasting 6·15 min. The regulation is simple, and enables potential differences between 5,000 and 50,000 volts to be accurately measured.

The absolute electrometer was of a similar pattern to Lord Kelvin's. The arms of the beam are short (6 cm.), their motion being limited by stops. The beam is mounted on a rigid brass plate, supported on the base-plate of the apparatus by four metal columns, 28 cm. high. The brass plate has a large circular opening through which the attracted disc can move. The edge of the opening is provided with three screws which carry the guard-ring, and enable it to be accurately adjusted. The movable disc, which was made of aluminium, was held accurately in the centre of the guard-ring by means of three fine horizontal threads. The movable disc is rigidly secured to the end of one arm of the beam, which was balanced by means of a counterweight on the other arm of the beam. The diameter of the movable disc is 5·95 cm.; it would be attracted by an infinitely large parallel disc at 1 cm. distance with a force of 5 g. when the P.D. was 10,000 volts. The base-plate of the apparatus, the columns, the beam, the disc, and the guard-ring (diameter, 22 cm.) are connected together, and to the earth. Beneath the attracted disc there is a horizontal insulated plate (22 cm. diameter), which was connected to the bodies, whose potentials were to be measured, by means of a terminal mounted on its vertical stem. The vertical distance through which the plate is moved is read off on a scale provided with a vernier. A potential difference of 40,000 volts can be measured accurately to 40 volts. The authors also describe a simpler construction of the apparatus. From the observations recorded, it was found that the electrometer could be used as an absolute instrument so long as the distance between the discs did not exceed half the breadth of the guard-ring.

G. MEYER—THERMO-ELECTRIC GENERATOR.

(Electrochem. Zeitschrift, 2, pp. 121, 122, 1895; Beiblätter, Vol. 20, No. 2, p. 141.)

An intermittent heating and cooling of the junctions was employed. One pole was warmed and the other cooled alternately. For the production of continuous, alternating, and polyphase currents the author uses the following arrangements:—(1) The junctions are rotated in front of stationary heating and cooling devices; (2) the heating and cooling devices are moved in front of the junctions; (3) the heating and cooling devices, as well as the thermo-electric generators, are stationary,

the intermittent heating being effected by moving screens which alternately bring an open and an imperforate part in front of the junctions; (4) the heating and cooling devices are stationary; the heating devices being controlled by regulators. In an experiment the author obtained an efficiency of 62 per cent.

P. WEISS—ON THE USE OF THE BALLISTIC GALVANOMETER WHEN THE TRANSIENT CURRENT IS NOT OF SHORT DURATION.

(*Journal de Physique*, 3, *Ser.* 4, *p.* 420; *Beiblätter*, *Vol.* 20, *No.* 2, *p.* 149.)

When the ballistic galvanometer is employed for measuring the difference of two opposite inductions, the E.M.F.'s do not in all cases commence exactly at the same instant if the Foucault currents in adjacent masses of metal oppose the two opposite induced E.M.F.'s unequally. In this case the needle begins to move at a velocity which corresponds to one of the transient currents, and has already moved through a certain angle when the transient current in the opposite direction reduces its velocity. The author has established by experiment that this retardation of one of the E.M.F.'s does not influence the strength of the impulse; it is also immaterial whether the opposite induced E.M.F.'s commence simultaneously, or whether one, by reason of Foucault currents, is caused to lag appreciably behind the other. Moreover, the author shows that the angle moved through by the needle between the two transient currents is an infinitely small quantity of the first order in relation to the observed amplitude, and that this amplitude measures the difference of the transient currents to an infinitely small quantity of the second order.

ANON.—ELECTRIC TRANSMISSION OF POWER IN THE MINES OF THE BLEIBERGER BERGWERKS-UNION, CARINTHIA.

(*Elektrotechnische Zeitschrift*, *Vol.* 17, *No.* 8, *p.* 125.)

This installation was carried out by Messrs. Ganz & Co., of Buda-Pesth. Power was taken from the Nötsch, a stream capable of furnishing 700 litres per second. Although the buildings and masonry are constructed with a view to utilising the whole of this power, the machinery at present installed is only capable of utilising one-half. The turbine is of the Girard type with horizontal shaft, capable of developing 285 H.P., at a speed of 170 revolutions per minute, with 360 litres of water per second, and an effective fall of 80 metres. The turbine is regulated by hand and by an automatic hydraulic regulator, whereby the speed is very accurately maintained at a constant value. The generator is an unipolar polyphase machine (Ganz system), capable of giving 200,000 watts at 3,000 volts, when running at 170 revolutions per minute. This machine, together with its exciter, is coupled directly to the turbine shaft by means of a leather coupling. The switches, regulating devices, and measuring instruments are mounted on a marble switch-board in the central station. The primary current at 3,000 volts is taken through bare wires 8 mm. diameter to four sub-stations, at the mouths of the Bellegarde, Kastel, Friedrich, and Rudolf shafts; these sub-stations being

provided with switch-boards, so that high-tension conductors are not used in any of the shafts and galleries. The secondary conductors consist throughout of insulated conductors, the conductors in the shafts being triple concentric armoured copper cables. The transformers transform the primary current down to 200 volts, those at the Bellegarde and Kastel shafts having a capacity of 50 kilowatts each, that at the Friedrich shaft 120 kilowatts, and the one at the Rudolf shaft 15 kilowatts. The secondary current is distributed as follows :—

1. In the Bellegarde shaft, two polyphase motors driving a winding engine for a load of 600 kilos. and 1 metre velocity, and also a pump throwing 600 litres per minute at 60 revolutions per minute, with a lift of 70 metres.

2. In the Kastel shaft, two polyphase motors for driving a winding engine similar to the above, and also a pump throwing 1,000 litres per minute at 60 revolutions per minute, with a lift of 70 metres.

3. In the Friedrich shaft, a polyphase motor of 160 H.P. at 500 revolutions per minute, for driving a horizontal mine pump having a maximum duty of 6,000 litres per minute, with a lift of 62 metres; this pump is so arranged that its output may be easily reduced to 3,000 litres per minute.

4. In the Rudolf shaft, a polyphase motor for directly driving the direct-current machine which was installed some years ago by Messrs. Ganz with the electric railway.

Special resistances are provided for starting the motors. The lighting of the sub-stations, the galleries, and the shafts is effected directly from the secondary mains, whilst a special transformer station is provided for lighting the offices and other buildings connected with the management. The whole of the installation will be in operation by the autumn of this year; the turbines, as well as the dynamo, motors, pumps, and winding engines, being manufactured by Messrs. Ganz & Co.

It may be mentioned that the greatest distance to which the current is supplied —viz., between the central station and the Friedrich shaft—is about 9 kilometres. To this distance one-half of the entire output will sometimes be supplied. In one part of the route, and more especially in a long, narrow street, the high-tension circuit meets the overhead low-tension circuits of the town; and in order to ensure that these circuits shall not be affected thereby, the Post and Telegraph authorities have caused the telegraph lines to be diverted at the cost of the Bleiberger Bergwerks-Union. At first, however, the telegraph lines are to remain *in situ* for a short time, to afford opportunity for experience being obtained as to how far, and in what way, the high- and low-tension circuits react upon one another.

ANON.—ON THE USE OF ACCUMULATORS WITH THE ALTERNATE-CURRENT SUPPLY AT ZÜRICH.

(*Elektrotechnishe Zeitschrift*, *Vol.* 17, *No.* 6, *p.* 80.)

The night load at the central station lighting this city being near the maximum output of the station, and the street mains, moreover, not being adequate for dealing with much heavier currents than those employed at the time, it was decided, when current was required for a large new music hall, to light the same

by means of direct currents from accumulators. These accumulators are charged during the day by means of rectified alternate currents, so that, in addition to relieving the night load, the day load is increased, and thus much more favourable conditions obtained for the economical working of the station. The consumption of current at this music hall (the "Neue Tonhalle") is equivalent to 2,000 16-C.P. lamps.

The plant is installed in the cellars of the Neue Tonhalle, and comprises a battery of accumulators, two current-rectifiers, the switches, and measuring arrangements. Moreover, in view of the novelty of the arrangement, an alternate- to continuous-current transformer was put in as a reserve.

The alternating current for the installation was taken mainly from two 30-kilowatt transformers, transforming down from 2,000 to 105 volts, and arranged at about 100 metres from the installation. From these transformers the secondary alternate current passed through double-pole switches to the rings of the rectifiers; between the rectifiers and battery and the distributing network, which is on the three-wire system, the switches and measuring instruments are inserted in the usual way.

Since the main transformers deliver the secondary current at a pressure of 105 volts, corresponding to the pressure in use, and in order to utilise as large a proportion of the available current as possible, two additional transformers, each of 15 kilowatts, were introduced; these transformers supplied their secondary current at a pressure of 55 volts, and thus gave 160 volts when in series with the main transformers.

In order to enable the number of windings of these additional transformers in circuit to be gradually increased in accordance with the increase in the back E.M.F. of the accumulators during charging, these transformers are provided with 10 terminals connected to a suitable switch. This switch is made exactly the same as an accumulator switch, so that the sections of the transformer cannot be short-circuited while the switch lever is being moved from one contact to another. Each section of the transformer corresponds to an increase of pressure of about 5 volts. By the use of this arrangement the regulation of the rectifiers is very much facilitated during charging, since the position of the brushes scarcely needs adjustment. The double-pole switches between the transformers and the rectifiers enable the direction of the current to be reversed if necessary. The rectifiers consist of two-part commutators with collecting rings for the reception and broad bars for the delivery of the current, and a small synchronous motor which sets the commutator in motion. In the Zürich installation, the motors for the rectifiers were 1 H.P. each, supplied with current at 65 volts from two special small 1-kilowatt transformers. For starting the synchronous motors, small continuous-current motors are employed, connected to the battery. When the rectifiers are set in motion, water-resistances are introduced into the continuous-current circuit, these resistances being ultimately short-circuited. The cut-outs for protecting the system against reversal of the current are polarised so as to provide for rapid and reliable operation, their electro-magnets, in addition to the main current coil, having a second weaker coil which receives current from the battery through a resistance and polarises the core in the same direction as the charging current; should a reversal of the main current take place, the two coils oppose one another, and the

automatic cut-out interrupts the current. By means of a suitable switch either rectifier can charge either half of the battery. The accumulator switch is provided with an automatic device for maintaining a constant pressure. The battery of accumulators, made by the Société Suisse pour la Construction d'Accumulators Électriques, Marly-le-Grand, consists of 118 cells of the Pollak type, S 44, and posesses a capacity at 2 × 105 volts, of 1,528 ampere-hours, with a four-hour discharge at 382 amperes, a maximum discharge current of 472 amperes, and a maximum charging current of 336 amperes.

The current-rectifiers were each constructed to deal with currents of 240 amperes at 110–160 volts. On each collecting ring rest four brushes; the current is taken from the rectifier by means of four rows of brushes, of which each alternate pair are connected together, and are adjustable relatively to one another by means of a hand-wheel. A second hand-wheel permits the whole system of brushes being adjusted around the axis as usual.

Each rectifier is mounted on a simple wood base, to which is also secured a small switch-board for the reversing switch and accessories. Beneath the stand is arranged the small continuous-current motor for starting, and the liquid resistance. The latter is an iron vessel, with an iron cover insulated therefrom and turning about a hinge, its rotation being effected by a hand-wheel through worm gearing; when switching in, sector-shaped iron plates secured to the cover, and arranged to move between plates secured to the bottom of the vessel, dip into the liquid. These sector-shaped plates are at first only immersed at their ends, so that the resistance is gradually reduced; as soon, however, as the cover comes down on to the vessel, two contacts pieces on the vessel and cover engage with one another and short-circuit the resistance.

The method of working with the rectifiers is as follows:—The synchronous motor is set in motion in the proper direction by means of its driving motor, and is then switched in, when the driving motor is stopped and the brushes applied to the rectifier. The charging lever of the section of the battery to be charged and the automatic cut-out are then switched in, and the double-pole switch supplying the alternating current to the rectifier brought into its "on" position. Before the circuit can be completed (which is done first through a resistance) it is necessary to ensure that the similar poles of the rectifier and of the battery are opposite one another. For this purpose two incandescent lamps in series are put in shunt with the resistance through which the circuit will be first completed, this being done by means of a key; if they incandesce strongly when switched in, then unlike poles are connected, and the reversing switch must be brought into its other position. After this, the circuit is completed through the switching-in resistance, which is gradually reduced and finally short-circuited, after which the brushes of the rectifier are adjusted to their most sparkless positions by means of the hand-wheels. As the charging progresses the E.M.F. of the rectified current is gradually increased as required by putting into circuit additional windings in the supplementary transformers.

The reserve alternate- to continuous-current transformer was made by the Maschinenfabrik Oerlikon. It consists of an alternate-current motor operated by the primary current at 2,000 volts, and takes 30 amperes when running at 330

revolutions per minute; and a shunt dynamo coupled directly thereto, which supplies 170 amperes, at 105 to 160 volts, at each of its two collectors.

The installation was carried out under the supervision of Herr Wagner, engineer, and Herr Büchler, assistant engineer, to the electricity supply station of the city of Zürich, in the July and August of 1895.

M. MAURAIN—ON THE ENERGY DISSIPATED BY MAGNETISATION.

(Comptes Rendus, Vol. 122, *No.* 5, *February, p.* 229.)

The object of these experiments was to ascertain how the loss of energy due to magnetisation varied with the frequency of the field employed.

The amount of heat generated was measured by means of a calorimeter, consisting of a glass vessel containing the iron under magnetisation, submerged in alcohol; the expansion of the liquid being measured by means of a capillary tube. This calorimeter was placed within a long solenoid, producing a uniform magnetic field. This coil was excited with an alternating current, and the rise in the capillary tube was noted, all care being taken to protect the calorimeter against external variations of temperature. The heat generated in the iron is due (1) to losses by magnetisation; (2) to eddy-current losses. The latter can be made practically negligible by using sufficiently thin laminations.

This calorimetric method, although very accurate and sensitive, requires two corrections to be made—(1) For external variations of temperature; (2) for losses due to radiation. The first is got over by making the surrounding atmospheric temperature as constant as possible. In the second case it is found that the curve representing the variation of level in the capillary tube as a function of the time, is a straight line within certain limits, beyond which the curve starts bending owing to losses of heat by radiation. It is between the above limits that the experiments are made.

The results of these observations show that the quantity of heat dissipated for a given time, diminishes with an increase of frequency, the rate of diminution becoming smaller. The author also made experiments with a copper cylinder, and found that the amount of heat generated by eddy-currents per period, with a given induction, increased about proportionally with the frequency.

Determinations were then made to ascertain whether the relative decrease observed was the same for different values of the magnetising field, and for this purpose curves were drawn at two frequencies (22·65 and 46·5) representing the variations in the dissipated energy as a function of the strength of the field. On measuring corresponding co-ordinates, it was found that the relative decrease was sensibly independent of the value of the field.

D'ARSONVAL and CHARRIN—THE ACTION OF HIGH-FREQUENCY CURRENTS ON BACTERIOLOGICAL TOXINES.

(Comptes Rendus, Vol. 122, *No.* 6, *February, p.* 280.)

The authors have extended their work on this subject by investigations on the influence of electricity on the toxines secreted by micro-organisms. MM.

Smirnoff and Kruger have carried out similar researches by employing continuous currents. This has, however, the disadvantage of inevitably producing chemical actions.

The preliminary experiments made with continuous currents, induced currents, or the extra current from a coil, have shown that the modifications produced in the toxines were not in proportion with the quantity of electricity employed. In the case of unidirectional induced currents it was found that the passage of 7 coulombs produced greater effects than 78 coulombs from a continuous current. It was concluded from this that the molecular disturbance produced by electrical discharges obtained from a coil, was greater than the effects due to electrolysis. In order to eliminate all electrolytic effects, alternating high-frequency currents were employed; the method adopted being similar to that proposed by M. D'Arsonval in 1893.

A high-tension transformer and two condensers are used in conjunction with a solenoid and a spark gap. The high-tension connections are made by means of platinum wires connected to a U tube containing the toxines. The tube is immersed in ice water to prevent any rise of temperature of the liquid due to the passage of the current.

The frequency obtained is a function of the conjugate capacity of the two condensers and of the self-induction of the solenoid. In these experiments the frequencies employed, as calculated from Thomson's formula, would amount to 225,000 oscillations per second. The effective strength of current passed through the toxines was increased by means of a special galvanometer, and amounted to about 0·75 ampere; the mean current-density being about 250 milliamperes per square centimetre. Experiments made on diphtheric and pyocyanic toxines show that the current has the effect of decreasing their power. The authors hope that these results may lead to the direct treatment of infectious diseases, as high-frequency currents have no injurious effect on the human system.

It was found that the pyocyanic toxine is attenuated by high-frequency currents in the same manner as that observed by Löffler. The effect varies according to the magnitude and duration of the current. In these experiments the effect due to the toxines was reduced to about one-half in about a quarter of an hour. The authors arrive at the following conclusions:—

1. That the high frequency attenuates bacteriological toxines.
2. That toxines so treated increase the resistance of the animals into which they are injected.

C. HENRY — INCREASE IN THE PHOTOGRAPHIC POWER OF RÖNTGEN RAYS BY THE USE OF PHOSPHORESCENT SULPHATE OF ZINC.

(*Comptes Rendus, Vol.* 122, *No.* 6, *February, p.* 312.)

A gelatino-bromide photographic plate is cut in halves, and one half is coated at the back with a layer of phosphorescent sulphate of zinc about 5 to 6 mm. thick. The coated half is placed in a slide and exposed to the light

of a candle; the slide is drawn out in steps, thus giving the plate a succession of gradually increasing exposures. The same is done with the other half of the plate. After development and fixing, a marked difference is observed in the density of the two.

It was found that the strip of greatest density on the uncoated plate, corresponded to a strip of the same density on the coated plate which had received one-seventh of the time of exposure. The results obtained with these rays differ widely. If, under ordinary conditions, a series of gelatino-bromide plates coated with sulphate of zinc be exposed to the Röntgen rays, it is found that in some cases the presence of the sulphate has made no difference.

The author is of opinion that it is not the gelatino-bromide, but the glass, which plays the part of absorbent. This emphasises the difference between the Röntgen and ultra-violet rays, and the important effect of glass and its thickness in such experiments.

If an object partly painted over with phosphorescent sulphate of zinc be photographed, the parts which have thus been painted over will appear transparent in the negative.

When experimenting in this manner with the Röntgen rays, a remarkable increase in their efficiency was noted; and it was found, by coating bodies which are absorbent to these rays with sulphate of zinc, that certain objects placed behind them, which otherwise would be invisible, became visible on the photographic plate.

The sulphate of zinc acts as a supplementary actinic source, and transforms otherwise inert Röntgen rays into photographic rays. It is probable that other sulphates than the above may possess this property, but sulphate of zinc has the advantage of its unchangeable nature.

M. MESLANS—INFLUENCE OF THE CHEMICAL NATURE OF BODIES ON THEIR TRANSPARENCE TO RÖNTGEN RAYS.

(*Comptes Rendus, Vol.* 122, *No.* 6, *February, p.* 307.)

The opacity of bodies to the x rays is dependent on their chemical constitution, as well as on their density and thickness.

The author has compared various metallic substances, their acids, and the metallic and organic salts they are capable of forming. The experiments were made chiefly on organic substances and on carbon. These are found to be very transparent to the x rays so long as, besides carbon, nothing else is present but the gases hydrogen, oxygen, and nitrogen. This opacity is, however, not found to be uniform, and appears to depend on the chemical constitution. The photographs were obtained by means of a Crookes tube placed at 20 cm. from the plate, with 30 minutes' exposure.

The diamond, graphite, anthracite, sugar carbon, produce a faint image, about equal in tone to that of wood or paraffin of equal thickness; while sulphur, selenium, phosphorus, or iodine produce very vigorous images, denoting great opacity.

Organic substances, ether, acids, and nitrogenous substances are easily traversed by the x rays, and produce a scarcely perceptible image.

But the introduction of such elements as iodine, chlorine, fluorine, sulphur, phosphorus, &c., has the effect of producing great opacity. Iodoform is very opaque, but alkaloids, picric acid, fuschine, and urea are very transparent. Metallic salts are very opaque, and are found to vary with the metal and with the acid.

The above facts are confirmed in the photographs of flesh and bones, the latter being opaque on account of their mineral constituents.

E. BRANLY—THE RESISTANCE OF THIN METALLIC FILMS.

(*Comptes Rendus, Vol.* 122, No. 5, *February, p.* 230.)

The author refers to the work done by previous investigators on the increase of conductivity of thin sheets of tin under the influence of electric discharges, and his own investigations in 1871 on the increase in the conductivity of thin films of gold, silver, and aluminium. Experiments were first made on platinised glass, which showed the above effect of decrease of resistance, and then on sheets of glass or ebonite covered with powdered metals or with more or less compact filings, and also with filings embedded in insulating powders. These various arrangements showed marked variations in the conductivity.

The same effects were obtained with thin metallic films as with discontinuous conductors, and it may be conceived that the electrical discharge has the effect of filling up the intermolecular spaces. The experiments were made at as constant a temperature as possible by means of a Wheatstone bridge. The films employed were 6 to 7 cm. long and 3 mm. wide, contact being made at the ends by means of brass strips. It is found that a decrease of resistance is only observed with very thin films. The phenomenon is produced by sparks discharged at a distance, but the greatest effect is produced by connecting a weakly charged Leyden jar direct to the sheet. Aluminium is the metal which shows the greatest decrease in resistance. A mechanical shock will re-establish the original resistance, as is the case with discontinuous substances. If left to itself, the film very gradually returns to its original resistance, but often not completely after 24 hours.

The author investigated the matter further, to ascertain whether this apparent decrease in the resistance might not be due to the contact resistance of the two metals, consisting of the film and the terminal plates—a phenomena which was discovered and published last year by the author. A sheet of gold, aluminium, or silver was placed between two plates of brass, and the current from a Daniell cell was sent through these contacts: their resistance did not alter with time.

In the above experiments, the alteration in the resistance can only be attributed to some effect in the films themselves. Under some conditions, such as the combination of lead and aluminium, the contact resistance would almost entirely disappear under the effect of the discharge, and that would be the more important phenomenon of the two.

A. NODON—EXPERIMENTS ON THE RÖNTGEN RAYS.

(Comptes Rendus, Vol. 122, No. 5, February, p. 237.)

The voltaic arc in air does not possess the properties of the Röntgen rays of traversing opaque bodies.

A sensitive photographic plate, enclosed in an opaque envelope and exposed to a 20-ampere arc at a distance of 0·4 metre during 15 minutes, does not show any perceptible image on development; but, under similar conditions, was very sensitive to the Röntgen rays. The ultra-violet waves, of which the arc is rich, will not pass through opaque bodies.

Gelatine screens of the different colours were traversed with equal facility by the Röntgen rays.

M. M. GOSSART and CHEVALLIER—ON A MECHANICAL ACTION PRODUCED BY A CROOKES TUBE, ANALOGOUS TO THE PHOTOGENIC ACTION DISCOVERED BY RÖNTGEN.

(Comptes Rendus, Vol. 122, No. 6, February, p 316.)

The authors observed a mechanical field of force in the neighbourhood of a Crookes tube, which was made manifest when a Crookes radiometer was placed in front of the tube. The radiometer was being used to demonstrate the rise of temperature in a Crookes tube. Instead of the vanes rotating, they remained stationary, when placed near the hot tube. If the vanes were first set rotating, and were then brought near the tube, they would take up an oscillatory motion, the oscillations becoming more rapid the nearer the vanes were brought to the tube. This effect was due to a field of force acting in an opposite direction to that due to heat. The authors further studied the direction and intensity of this field of force by means of a radiometer. They ascertained, after experiments on about 20 substances, that this field of force traverses, or is interrupted by, the same mediums as the x rays.

It was further found that, when the radiometer was placed in the field of the Crookes tube, the force resisting the vanes was modified by discharges from an induction coil, or by statically electrified bodies; and they were vigorously disturbed by the presence of a magnet. By moving a magnet round the radiometer the vanes could be set in motion.

This, then, offers a convenient method for making qualitative and quantitative investigations on the radiations from a Crookes tube, and for this purpose the authors used a Melloni bridge, consisting of a Locatelli lamp, a radiometer placed 30 cm. from the lamp, to produce about 15 revolutions per minute, and a Crookes tube moveable around its vertical axis and having a divided scale showing the direction of the cathode beam.

When the cathode rays are started the vanes stop rotating. On stopping the rays, the vanes remain stationary for about five minutes, notwithstanding the presence of the lamp. A method of restarting the vanes is to submit them to the action of the anode rays by approaching the tube to a few mm. from the radiometer.

The vanes then receive an impulse in the opposite direction, and take up their normal rotation.

The authors found that the above effect of the vanes stopping for five minutes took place when working with a Rhumkorff coil, but not with a Wimshurst machine.

H. BECQUEREL—ON RADIATIONS EMITTED BY PHOSPHORESCENCE.

(*Comptes Rendus, Vol.* 122, *No.* 8, *February, p.* 420.)

Mr. Ch. Henry has recently published the discovery that phosphorescent sulphate of zinc, placed in the path of the rays emitted from a Crookes tube, increase the intensity of the radiations passing through the aluminium.

M. Niewenglowski has also observed that commercial phosphorescent sulphate of calcium emits radiations capable of passing through opaque bodies. This property belongs to various phosphorescent bodies, and particularly to the uranium salts, whose phosphorescence lasts a very short time. The following experiment was made with the double sulphate of uranium and potassium, whose crystals form a thin transparent crust:—A Lumière gelatino-bromide sensitive plate was wrapped up in two sheets of very thick black paper. On the outside of the paper was placed a layer of the phosphorescent crystals, and the whole exposed to sunlight for several hours. When the plate was developed, the image of the phosphorescent portion appeared.

If a metallic object be interposed between the phosphorescent layer and the plate, its image will appear on the plate. The same experiments were repeated, and the same results obtained by placing a sheet of glass between the photographic plate and the phosphorescent layer in order to exclude the possibility of any chemical action.

A. BUGUET and A. GASCARD—THE ACTION OF "x" RAYS ON THE DIAMOND.

(*Comptes Rendus, Vol.* 122, *No.* 8, *February, p.* 447.)

The authors find that by employing the x rays it is possible to distinguish the diamond from its imitations, which invariably consist of substances of comparatively great opacity to these radiations. By long exposures the silhouettes of the real diamonds disappear altogether, whereas the imitations act as opaque bodies. The same test is applicable to jet. In addition to this graphical method, the authors have employed an optical method, dependent on fluorescence. The specimens are interposed between the Crookes tube and a sheet of paper coated with the fluorescent material, such as platino-cyanide of barium. The true substances produce lighter shadows than their imitations.

This method possesses the advantage that the gems can be tested in their settings.

M. PILTCHIKOF—ON THE EMISSION OF RÖNTGEN RAYS FROM A TUBE CONTAINING A FLUORESCENT SUBSTANCE.

(*Comptes Rendus, Vol.* 122, *No.* 8, *February, p.* 461.)

With the object of obtaining more powerful effects from a Crookes tube, and of reducing the time of exposure for taking photographs, the author employed a Puluj tube, which is more fluorescent than glass. The time of exposure was considerably reduced.

The use of a small Voss machine in conjunction with such a tube is about equivalent to an induction coil and an ordinary Crookes tube. By employing a coil and Tesla apparatus the exposure was ultimately reduced from 20 minutes to 30 seconds.

MM. DARIEX and ROCHAS—ON THE CAUSE OF THE INVISIBILITY OF THE "x" RAYS.

(*Comptes Rendus, Vol.* 122, *No.* 8, *February, p.* 458.)

The following experiments were made with the object of measuring the transparency of the different substances in the eye to the Röntgen rays, and to ascertain whether these (amongst which crystallin has an index of refraction very close to that of glass) do not offer, as does the latter, a high resistance to the passage of these rays.

In the first series of these experiments a Wimshurst machine was used, and to the negative pole of which a Crookes tube was suspended by the cathode, and the positive pole connected to the anode. The experiments were made with fresh pig's eyes, as these are comparable to the human eye.

An exposure of 20 minutes was given to a plate wrapped up in four sheets of black paper, and the eye almost touching the bottom of the tube. It was found that the eye behaved to the x rays as an opaque screen.

The object of a second series of experiments was to make a careful comparison between the transparent portions of the eye with other opaque tissues, especially those of the hand. An induction coil was used, worked from two cells. The eye was so placed, that the x rays could only pass through its transparent portion. It was found that the eye, although exposed more directly to the rays, is more opaque than the muscles of the hand, but far less opaque than the bones. On closely examining the developed plate, a darker spot was observed in the image projected by the eye, which seems to indicate a greater opacity of the axial part of the eye which is used for vision.

M. DE HEEN—AN EXPERIMENT SHOWING THAT THE "x" RAYS EMANATE FROM THE ANODE.

(*Comptes Rendus, Vol.* 122, *No.* 7, *February, p.* 383.)

To demonstrate this, the author places between the Crookes tube and the sensitive plate a lead screen in which several apertures are made which allow the rays to fall on to the plate. The images produced on the plate showed that the x rays emanate from the positive pole, and not from the negative pole; they are anode rays.

A. RIGHI—ELECTRIC PHENOMENA PRODUCED BY RÖNTGEN RAYS.

(*Comptes Rendus, Vol.* 122, *No.* 7, *February, p.* 377.)

The following is a *resumé* of some experiments made by the author contemporaneously with those of MM. Benoist and Hurmuzescu on the dispersion of electric charges produced by Röntgen rays :—

A Mascart electrometer was connected to the body, on which the *x* rays were directed. The Crookes tube and apparatus producing the discharge were enclosed in a metal case connected to earth. The part of the case nearest the tube consisted of a thick plate of lead having a round aperture 10 cm. diameter, at its centre, covered with a thick piece of aluminium, through which the rays passed.

It was found that a metallic disc connected to the electrometer rapidly lost its charge, whether this was positive or negative. The duration of the action to cause a fall of potential from 7 volts to 3·5 volts, was practically the same for either sign. With an initial positive charge the discharge is not complete ; but with a negative charge, not only is the body discharged, but a positive charge is observed. If the Röntgen rays be directed on one of the author's photo-electric couples, a positive or negative deflection is observed according to the nature of the metals constituting the couple, as is the case with the ultra-violet rays. It was also found that a disc under ordinary conditions is positively charged when exposed to the new rays, as is also the case with the ultra-violet rays. With the same disc the final positive potential is the same whatever be the initial potential sign of the disc, be it either positive, negative, or zero. This final potential was higher with copper than with zinc, and still higher with retort carbon. It was also found that a sheet of glass nearly 1 cm. thick placed in the path of the *x* rays did not stop their action, but only weakened it, as is also the case with a thick sheet of aluminium, a thick block of pine, or the hand.

J. J. BORGMAN and A. L. GERCHUN—ACTION OF THE RÖNTGEN RAYS ON ELECTROSTATIC CHARGES, AND ON THE EXPLOSIVE DISTANCE.

(*Comptes Rendus, Vol.* 122, *No.* 7, *February, p.* 378.)

According to J. J. Thomson's recent experiments, the positive and negative charges are equally dissipated by the action of the rays. The authors' experiments do not quite confirm these results.

A positively charged disc connected to a fairly sensitive electroscope, lost its charge immediately when subjected to the action of a Crookes tube placed fairly near. For greater distances (1 m.) the dissipation took place at a slower rate. After the loss of the positive charge the leaves of the electroscope diverged anew and showed a negative charge, which increased up to a certain value.

When the disc was charged negatively, the electroscope showed a much slower dispersion, which ceased at a certain point. The loss of charge was smaller with small distances, and became great when the disc was removed from the tube.

A sheet of aluminium 1 mm. thick, connected to earth, weakened the action of the rays, but without changing their character in any way. These experiments tend to show that the rays emanating from a Crookes tube can communicate a negative charge to a conductor.

In another experiment the rays fell on two small platinum balls connected to a small Rhumkorff machine. The distance between the balls was too great for a discharge to take place; but under the action of Röntgen rays sparks immediately took place. A thin sheet of aluminium connected to earth, or sheets of ebonite, placed in the path of the rays, did not sensibly alter their action. The Röntgen rays, as well as the ultra-violet rays, have, then, the property of increasing the explosive distance of a static discharge.

J. REYVAL "LE SECTEUR DE LA RIVE GAUCHE" ELECTRICITY SUPPLY IN PARIS.

(*L'Éclairage Électrique, Vol.* 6, *No.* 5, *p.* 194.)

This company is at present the most important in Paris, on account of the great distances of distribution. High-tension alternating currents are employed. The supply station is situated on the bank of the Seine, at a distance of about 1 kilometre from the Auteuil Viaduct. The coal is discharged from the barges by means of an electric crane worked by an alternating-current motor.

The station consists of two buildings joined to one another: the one, containing the boilers, is 94 m. long by 18 m. wide; the other, containing the machines and switch-board, is 105 m. long by 14·5 m. wide. The station contains at present seven boilers, but this number will eventually be increased to 20, arranged in four sets of five boilers. There are at present three sets of 400 kilowatts each, and two exciting sets. When the station is completed it will contain 10 such sets, two of the alternators and boilers being kept as spares. There will also be two spare exciting sets.

In the centre of the buildings are placed the surface condensers and pumps, a complete set of feed-water pumps being provided. All this plant is placed in a pit, in order to bring it as near the level of the water as possible. The grouping of the machines is so arranged that any one of the boilers or machines can be made independent of the others, and the engines are arranged to work condensing or non-condensing.

The boilers are of the multitubular type, the chief particulars of which are as follows:—

Pressure	12 kgm. per sq. cm.
Heating surface of the tubes	183·2 sq. m.
Total heating surface	210 sq. m.
Grate surface	4·5 sq. m.
Number of tubes	108
External diameter of tubes	0·100
Length of tubes	5·400
Volume of water	13·300 cub. m.
Volume of steam	4·900 cub. m.

The steam pipes are so arranged that any group of boilers can be made to feed any engine. In each branch is placed a water separator and pressure valve, allowing the pressure to be varied between 8 and 10 kilogrammes. The boilers are designed for a pressure of 12 kilogrammes, in order to cope with any accidental overloading of the station. The boilers are fed by four donkey pumps, each capable of delivering 30 cubic metres of water per hour, corresponding to the feeding of half the plant working at full load and condensing.

The main engines are of the compound horizontal type, coupled direct to the alternator spindle. Each of the cylinders is steam jacketed.

The following are the leading particulars of these engines :—

Diameter of the H.P. cylinder	0·550 m.
,, ,, L.P. ,, ...	0·850 m.
Travel of piston	0·900
Revolutions per minute	125

Initial pressure of steam on the small piston, 8 to 9 kilogrammes.

I.H.P. corresponding to an output of 400,000 watts, 700 H.P

Two sets of condensing apparatus are employed. The condensing surface of each condenser is 565 square metres, the tubes have a diameter of 0·020 metre, their length 3 metres, and the number of tubes 3,020.

As regards the electrical apparatus, each alternator has a normal output of 400 kilowatts, and is of the stationary armature and revolving field type. The armature sheet consists of two cast-iron rings strongly bolted together, and resting on the combined bed-plate. The field magnet has radial poles bolted to a cast-iron yoke ring, the field windings being wound on independent zinc formers. The diameter of the armature bore is 2·992 metres. At the normal speed of 125 revolutions the alternator is capable of supplying 133 amperes at 3,000 volts, at a frequency of 42 periods per second.

The exciters are of the iron-clad multipolar type, having six poles, and direct-coupled. At the normal speed of 200 revolutions per minute the output is 630 amperes at 110 volts. The engines driving the exciters are of the single-cylinder horizontal type, and their indicated H.P. at normal load is 125.

The switch-board stands above a platform placed 2·5 metres above the ground and consists of 14 panels, forming a length of about 17·5 metres and a height of about 3 metres. Ten of these are alternator panels, provided with the necessary synchronising apparatus for connecting the machines in parallel. Main bars are used for connecting the alternators to the circuits, and auxiliary bars are provided for connecting any of the alternators to an auxiliary load. The two auxiliary resistances are capable of absorbing 300 kilowatts at 3,000 volts; their switches have 30 contacts, and the two rheostats can be connected in parallel if required.

The following device is employed to prevent fluctuations in the lights when a machine is thrown in parallel :—

Before directly coupling to a circuit an alternator which is running on the artificial load, the secondary circuits of two transformers are connected through a variable resistance, the primary circuit of one being fed from the main bars, while the primary circuit of the other is connected to the auxiliary bars.

The resistance in the secondary circuits is then diminished, these circuits having been connected to oppose one another, so that the alternators are to some extent magnetically coupled through the transformers. The mutual reactions which are set up greatly facilitate the paralleling of the alternators.

An automatic rheostat is employed for maintaining a constant supply voltage by altering the field of the exciters.

The high-tension switches employed have mercury contacts, and are of a new design.

The contract for the mechanical and electrical portion was carried out entirely by the firm of Schneider & Co., of Creusot, and the switch-board by MM. Lombard, Gerin, & Co., of Lyons.

The distribution circuits form two distinct groups. One consists of a high-tension circuit at 3,000 volts, and the other of a secondary circuit at 110 volts.

The primary circuit has a length of 20 kilometres, and consists of a ring main connected to the station by two feeders. The primary mains are concentric, insulated with paper impregnated with compound, and also with jute; they are further double-lead-covered and steel-armoured. They were manufactured and laid by the Société des Téléphones according to the patents of Felten & Guilleaume. The sections employed vary from 200 sq. mm. to 25 sq. mm., and the lengths from 170 metres to 300 metres; and they are connected at junction boxes, all of which are filled with a special insulating material before being closed. To the primary circuit are connected branches to consumers and branches to the sub-station. The cables are laid directly in the ground, and are protected by a galvanised iron grating.

At present four sub-stations are in use, their outputs varying from 15 to 75 kilowatts. The low-tension mains consist of three bare copper strips carried on porcelain insulators placed in concrete troughs. The compensating cable is placed at the side, and not in the centre, in order to diminish as much as possible the effects of impedance, of which the influence varies with the distance apart. The sections employed for the secondary cables are 1,000 sq. mm., 500 sq. mm., 250 sq. mm., and 125 sq. mm.

ANON.—THE THREE-PHASE TRAMWAY OF LUGANO.

(L'Éclairage Électrique, Vol. 6, No. 8, p. 365.)

The first application of the three-phase system for traction purposes has recently been realised at Lugano (Switzerland). The generating station is situated near Maroggia, at a distance of 12 kilometres from Lugano. It utilises the hydraulic power of the Arogno torrent. A three-phase generator of 150 H.P. is driven from a 300-H.P. turbine, thus allowing of the installation of a second turbine.

The frequency is 80, and the working pressure 5,000 volts. The exciter is direct-coupled to the alternator spindle. At Lugano the pressure is transformed down to 400 volts. The cars carry a double trolley, and the rails are utilised as one conductor.

The use of the three-phase system offers the following advantages:—The transmission of power from a distant source of power. The elimination of commutators on the motors. The speed of the cars remains constant, irrespective of load or gradient. At Lugano the maximum speed is 15 kilometres per hour. A hand regulator allows intermediate speeds to be obtained. The absence of any electrolytic action is also a great advantage. The chief disadvantage against this system is the use of two overhead conductors and a double trolley.

HENRI MOISSAN—THE STUDY OF CARBIDE OF URANIUM.

(*Comptes Rendus, Vol.* 122, *No.* 6, *February, p.* 274.)

In this paper, the author describes the mode of preparation, the properties, and the analysis of carbide of uranium. The following are the conclusions arrived at:—Uranium, heated in an electric furnace in the presence of an excess of carbon, produces a definite crystalline carbide of the formula $C^3 Ur^2$. This new compound is decomposed when in contact with cold water, yielding about one-third of its carbon in the form of a gas, methane. The other portion of the carbon produces a mixture of liquid and solid carbides and of bituminous substances. The presence of hydrogen in the gaseous mixture may be due to the secondary action of an oxyhydrate of uranium, which must be a powerful reducing agent.

These experiments show that the decomposition of certain carbides by cold water may be fairly complex as compared with the crystallised carbides of the alkaline earths, having the formula C^2R, which only yield pure acetylene. This reaction is all the more curious that it yields hydrogen carbides in the gaseous, liquid, or solid condition, the starting point of organic compounds, by the simple action of water at the ordinary temperature on a metallic carbide.

M. VIGOUROUX—ON SILICATE-COPPER ALLOY.

(*Comptes Rendus, Vol.* 122, *No.* 6, *February, p.* 318.)

With regard to the preparation of this compound by means of the electric furnace, the process is as follows:—Mixtures of pure silicon and copper are subjected to the action of the electric furnace: after a few minutes they will have combined to form very homogeneous liquid metallic masses. Contrary to what took place with other metals, the substances thus formed remained homogeneous during the time that they remained liquid. By varying the proportions of the two constituents a number of alloys were obtained, differing from one another by about 5 per cent. in their amount of silicon The alloy containing 5 per cent. and below this, has a clear metallic lustre and a sharp whitish fracture, which, however, soon vanishes on exposure to air, and becomes about the same colour as brass; it appears very ductile, and is easily hammered out. The 10 per cent. alloy has a pale grey fracture at first, but on exposure to air changes slowly to a reddish colour; it is harder and less malleable. The 15 per cent. alloy has a steel-grey appearance, and is also tarnished on exposure to the atmosphere; it is very hard and brittle.

All these alloys have the common property that when they are treated with acids they yield a salt of copper and of silicon; they are exempt from free silicon, and completely homogeneous. It is only about 20 per cent. alloys which become non-homogeneous, and these are still hard and brittle; their fracture is of a brilliant and purple nature. If an alloy containing still greater proportions of silicon be powdered and treated with nitric acid, it will lose its copper, and leave an abundant dark residue, in which silicon will be recognised, and also a black substance having all the characteristics of crystals of silicon. By heating 10 per cent. mixtures of the metal and silicon for sufficient time to volatilise the excess of copper, a mass was finally obtained in the crucible which cooled very slowly, containing masses of well-defined crystals having a formula $Si\ Cu^2$.

This alloy is a very hard substance, of a steel-grey colour and clean section, but assuming after some time a reddish colour. The density is 6·9 at 18°. Halogens attack it, with incandescence. At a red heat oxygen and dry air convert it into a silicate, and oxidation takes place in cold damp air. It reduces water to steam. All the hydroxides attack it. Acids produce a copper salt with a deposit of silicon, which hinders the reaction. Potassium darkens it.

A. RIGHI—ON THE ELONGATION OF AN ELECTRIC SPARK PRODUCED BY THE MOTION OF THE ELECTRODES.

(*L'Éclairage Électrique, Vol. 6, No. 6, February, p. 262.*)

The length of an electric spark between two conductors surrounded by a gas under definite conditions depends on the difference of potential of the two conductors, and under ordinary circumstances increases with it.

The author has previously shown that very long sparks can be obtained at the surface of water, these taking place in the layer of air close to the liquid. The sparks are small at first, and can be drawn out to a comparatively great length with a much lower potential than would be necessary to produce the same length of spark under ordinary circumstances.

In the following experiments, the author endeavoured to ascertain whether the same effect could be obtained with ordinary sparks. A condenser of large capacity is discharged through a high-resistance circuit. The circuit contains three micrometer gaps, A, B, and C. The balls of the first one are, to commence with, separated to a certain distance apart, while the others remain in contact. Then if, as soon as the spark is established at A, the balls of the second exciter, B, be drawn apart, another discharge will take place simultaneously at B; and the same can be done at C, although the potential to which the condenser was charged was only sufficient to overcome the resistance of the gap A The B and C sparks may, then, be considered as an elongation of the A spark, the combined length of which is greater than would correspond to the potential available.

In carrying out the experiment practically, it suffices to employ a single micrometer or exciter, and to increase the gap the moment the spark is established, and in this way very long sparks are obtained. The discharge circuit contained he main variable spark gap, with a movable electrode, also a fixed gap exciter,

and between the two a resistance consisting of a column of water of variable length. The variable spark gap was obtained by means of an aluminium arm 38 cm. long, fixed to an ebonite cylinder mounted on a spindle and rotated by clockwork. A rapid angular velocity could thus be imparted to the arm, corresponding to about 40 revolutions per second. If the arm be rotated while the condenser is charged, sparks are to be seen at both gaps. The spark drawn out by the movable arm will be in the form of an arc. Its length is about 20 cm., and that of the small spark about 1½ cm. In order to obtain the best effects, the column of water has to be adjusted within certain limits. The spark has special characteristics: at the movable electrode it is of the second order, viz., white, faint, and thin, and surrounded by a yellow gaseous region; it, however, becomes red (third order), on account of the supplementary resistance due to the first portions of the spark itself.

Owing to the centrifugal motion of the air caused by the rotation of the aluminium arm, the spark and yellow region surrounding it take the shape of a riband, the spark being at the edge of the riband closest to the axis of rotation. The length of the spark depends on the velocity of the arm, but does not always increase with it, there being a certain velocity producing the longest spark. This is no doubt due to the effect which the moving air has of dispersing the heated gases forming the spark. This velocity is greater the smaller the capacity of the condenser.

The sparks thus obtained resemble superficial sparks, or those obtained over the surface of water, by their considerable length and the way in which they are drawn out; the former, however, are not due to a lateral discharge, as is the case with the latter.

By a small alteration in the arrangement of connections in the above experiment, a very brilliant and noisy spark is obtained, and which is analogous to the superficial spark. This is obtained by utilising the spark which has been formed, and by discharging the condenser through the heated gases. A small knob is placed where the end of the movable arm stops, and is connected directly to the second ball of the small exciter.

This has the effect of forming a new path for the discharge, instead of its passing through the water resistance, and a brilliant noisy spark will be formed, passing through the path occupied by the previous spark, and consisting of hot rarefied air. This brilliant spark does not allow the previous pale one to be distinguished. The sparks formed in the above manner have the peculiarity of being very sinuous.

P. DELAHAYE—RESEARCHES ON MATERIALS USEFUL IN THE MANUFACTURE OF INCANDESCENT LAMP FILAMENTS.

(*L'Éclairage Électrique, Vol. 6, No. 6, February, p. 273.*)

The author summarises the different researches which have recently been made to obtain in electric incandescent lamps the brilliancy imparted by the rare oxides employed in incandescent gas mantles. A German company endeavoured to

introduce into the carbon filaments certain oxides used in the manufacture of the Auer burner. Filaments were made containing 10 per cent. of zirconium, and some were entirely coated with the oxide; they were, however, fragile, absorbed too much power, and rapidly lost their illuminating power.

The main difficulties to contend with, are due on the one hand to the differences of expansion of the carbon and the oxide, and on the other hand to the fineness of the filament. In an electric lamp the amount of light equivalent to a candle is emitted from a surface varying from 2 to 6 sq. mm., whereas in the Auer mantle this amount of light is emitted from a surface of 33 sq. mm.

The manufacture of hitherto unknown carbides in the electric furnace—notably carbide of silicon, introduced in America under the name of carborundum—led to researches in a new direction. Filaments of a pure carborundum can be obtained by a special process, having great elasticity and a rigidity comparable to that of carbon, but of very high resistance. Carbides of boron have not yielded satisfactory results; solid mixtures of silicon and boron could not be tried, on account of the difficulty due to differences of expansion.

With filaments of carbide of silicon the globe darkened so rapidly that a 105-volt 16-C.P. lamp, requiring 3·65 watts per candle, required 4·4 watts with the current at 120 volts after 60 hours. There is also a tendency to break at the joints, and it is believed that the continuous action of the current, combined with the high temperature and the vacuum, cause the carbide to decompose.

According to MM. Mielke and Vorringen, carbide of calcium yields more encouraging results. Their experiments were published in the *Elecktrische Anzeiger* (20th October, 1895), giving curves and tables for lamps working from 1 to 50 and 100 candle-power. A comparison made with ordinary incandescent lamps does not show a great difference. With carbide of calcium the light would be more brilliant and agreeable; the lamps would be strong, and more regular with regard to resistance; the surface would be only two-thirds of that of pure carbon, with equal voltage, candle-power, and efficiency. The new filaments would be as hard as diamond.

The author considers that, to compete satisfactorily with the incandescent gas lighting, it will be necessary to increase the efficiency of the incandescent lamps to 2·5 watts, and even to 2 watts per candle; and, according to the lamp tests carried out during the last months in England and America, this result does not appear near at hand.

JOURNAL

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ERRATA IN PART 122.

On pp. 335 and 336 (article by C. Henry) read "sulphide of "zinc" instead of "sulphate of zinc."

On p. 339 (article by H. Becquerel) read "sulphide of zinc" instead of "sulphate of zinc," and "sulphide of calcium" instead of "sulphate of calcium."

On p. 337, 5th line, read "fuchsine" instead of "fuschine."

On pp. 339 and 342 read "Ruhmkorff" instead of "Rhumkorff."

approved by the Council:—

From the class of Associates to that of Members—

W. S. Graff Baker.	J. B. Saunders.

From the class of Students to that of Associates—

Reginald Charles Carty.	Robert Loraine Gamlen.
Edward Graham Fleming.	Herbert Bryan Poynder.

Mr. J. Morris and Mr. H. C. Donovan were appointed scrutineers of the ballot for new members.

The CHAIRMAN: We have now, gentlemen, the remainder of the evening for the discussion of Mr. Dane Sinclair's paper.

Mr. Kingsbury.

Mr. J. E. KINGSBURY: Mr. Sinclair brings forward two rather important questions—the call-wire system and the flat board—with the view of improving the telephone service, and to some extent reduce its cost. Those are the two points which I think I may say form the essence of the paper. With the objects sought to be attained it is impossible to hold other than one opinion. We must be all in entire sympathy with Mr. Sinclair in his aims, and we must recognise fully that he desires to obtain those results which I have referred to. It is open for some of us to say, perhaps, that there are other ways of obtaining those results, and it may be that we might even go so far as to remark that Mr. Sinclair's methods do not attain the results he aims at. It will be necessary for me to some extent—and I may as well define my position at once—practically to take up that position on the two important points. Before I do so, I may say, to place myself right, that I find it impossible to take up that position without recognising fully the aims that Mr. Sinclair has in view. Now, in the first place, I would refer to the call-wire system. Of course the call-wire system is by no means a novelty. It was described in this room by Sir Frederick Bramwell, on the 1st March, 1883. He said, "The Law system seemed to me to "work extremely well when I saw it in operation in Philadelphia;"* and that opinion was one that was held by a great many others at that date. I am sure that amongst those who held it it is consistently held, and reasonably held, and is, curiously enough, the result of their experience. I do not think I have ever come across an advocate of the Law system who has not consistently held the position that it facilitates the service, and has desired to develop a service by that means. On the other hand, we have to consider that some experience has been gained between 1883 and 1896. It happens that that system which Sir Frederick Bramwell saw at work in Philadelphia is now in process of being discarded there. In October, 1883, Mr. Lockwood was attending the Telephone Convention at St. Louis. The Law system was under

* "Practical Applications of Electricity" (Institution of Civil Engineers, 1884, p. 51).

discussion then—and it is quite impossible to deal with any question of early telephone history without quoting Mr. Lockwood. Mr. Lockwood said: "About a couple of months ago I was in "St. Louis, where the Law system has been in operation for some "years. St. Louis, although a city of very large population, has "a very small telephonic population. Whether there is any "connection between the two things—the Law system and the "sparsity of the telephone subscribers—I am not prepared to "say."* Now, in looking up that extract, it rather gave me a suggestion, which I followed up. I looked up the English records, and there are some very full records in the Committee's report.† Perhaps I expected to find that the English towns using the Law system were also sparsely populated telephonically, but I did not. I found that they stood very well on the list of those towns having a good number of telephone subscribers. But I found one set of records in this Committee's report, which is a statement showing the number of subscribers in the four large Scotch towns during the last five years. Two of those towns—Dundee and Aberdeen—have been using the Law system—that is, the call-wire system—during that period. One of those towns—Edinburgh—has been using the indicator system. Another of those towns—Glasgow—has been using both during that period. The number of subscribers in Aberdeen during the last five years has increased 82 per cent.; the number of subscribers in Dundee has increased 57 per cent., and in Edinburgh 140 per cent. Now perhaps that is not enough for us to assume that it is in any way a conclusive comparison, because four towns are not sufficient. I have not had the opportunity of comparing it with other towns. It suits the present case, but it is not enough to be taken as at all conclusive. I only indicate it as a suggestion to carry the matter further, and see how it compares in other towns of equal character. In Glasgow, since the Law system has been introduced the proportional increase of subscribers has considerably fallen off, but there again the time (two years) has not been sufficiently long to take it at all as a conclusive matter. Five years is a very good period in

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* Tel. Con. Reports, 1884, p 42.

† Report of House of Commons Select Committee on Telephone Service, 1895.

Mr. Kingsbury. which to strike an average. I simply put it forward as a suggestion as to whether the Law system is or is not a progressive system. The system in Philadelphia is now in process of being discarded, and St. Louis is preparing to discard it. These are points which it seems to me are peculiarly adapted for being considered on the subject of this paper. Another thing that I looked at from a statistical point of view was to find the extent to which subscribers make use of their telephones on various systems. I find that Glasgow has six and a half calls per day per subscriber. In the records they appear as "messages," as 13; but as Mr. Sinclair and myself are more familiar with describing them as "effective calls," I have divided them by two, so as to make Glasgow six and a half calls per day. Compared with Liverpool, that is just one-half of the use which is made of the telephone. That is another point we have to consider. If the Law system facilitates subscribers, and is considered useful to subscribers, we must consider how much they use it. It appears that all the exchanges using the Law system are somewhat below any other similar town of their size in England and the United Kingdom. In any case the Law system subscribers do not use the telephone to the same extent as they do on the indicator system. It is quite useless for me to suggest to you reasons for that. We might go on talking for a very long time, and might have very many different opinions expressed upon it. I simply give you the facts. Mr. Sinclair refers to the difficulty of going through the exchanges, and making what we call the "trunk calls." I suppose that the thick and thin advocate of the Law system would say that that difficulty does not exist; but we agree with Mr. Sinclair that it does exist, and its existence seems to me to be rather a reason for not pursuing that system. If we are to indulge in any ideals at all, we ought to have the idea that the communications between towns in the sweet by and by will be about as easy as communication between the streets of one town now; and if there is any difficulty, it seems to me a reason for not pursuing that system. Then, again, Mr. Sinclair has told us that the subscribers like the call wire,—that 95 per cent. of them in Glasgow prefer the call *wire to* the indicator system previously in use. The weak point

about that is that we have not got all the materials before us to enable us to make up our minds. What we want to know is, What was the indicator system previously in use? in order that we should be able to form an opinion of what is the value of the opinion of 95 per cent. of the subscribers. Personally, I attach far more importance to Mr. Sinclair's statement that, having studied the matter as an engineer, he is of opinion that the Law system should be introduced. That, I think, is a strong argument. But the opinion of the subscribers as to what they ought to be served with, I think, is rather a weak argument. I hope the telephone subscribers here will forgive me if I tell them that they ought to be treated like children. They do not know what is good for them. It is the people who supply the telephone service who should tell the subscribers what is good for them, and give them what is good for them, and not what they *like*. If you asked subscribers what they liked, they would probably tell you something which is not good for them. With that I may conclude my remarks in regard to the Law, or call-wire, system.

Mr. Kingsbury

Then I come to the next important feature of Mr. Sinclair's paper, namely, the flat boards. In his paper the author remarks that flat boards had been in use previously, and as they were not used for saving spring jacks, it was difficult to see what they were installed for, excepting that they were more easy to operate. That is rather begging the question. We shall have to consider presently what the facility of operations are, but I think it is possible to find another reason for making flat boards, without suggesting that they were easier to operate, and it is this: The flat boards were originally introduced on the Law system, and before the introduction of the multiple switch-board. At that time it was necessary to have a certain set of subscribers connected to one switch-board, and to have inter-communication by what we call cross connections between one set of subscribers and the other. In that case the lines ended in plugs, which were placed in the middle of the switch-board, and there were connecting bars across in which two plugs were put in order to complete the connection. If the two could be connected on that one board, it would save the necessity of cross-connecting to

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another board and introducing the difficulty that Mr. Sinclair plainly states—the trunk line difficulty. If you can have a board with plugs along the middle of the table, and put operators on each side of them, it is obvious you can increase the capacity of that table, and reduce the necessity for cross connections. That, I think, was the introduction in the first instance of the necessity or the advantage of the flat board. Subsequently to that, when the Law system was extended so as to use multiple switch-boards, the jacks were reduced to a microscopic size, more or less like honey-comb, and each operator was given the whole of the jacks in the exchange. If that points to anything, I think it points to the experience of the difficulty of one operator passing another with flat boards; and that, I think, is one of the difficulties which we shall have to refer to presently. Then, in the introduction of flat multiple switch-boards, with the object of saving jacks, I think we have the switch-board of Mr. Hawes, which was installed about 1884.* The next was—although I am not aware it has ever been put in practice—a design made by Vail & Seeley in 1888,† and really the number of spring jacks that Messrs. Vail & Seeley saved is simply fabulous. After that we have a design of Messrs. Jackson & Sinclair in 1889.‡ Vail & Seeley saved an immense number of jacks—double the number that Mr. Sinclair saved. That is, they say so. As a matter of fact they did not. They make their board of a different design, but they simply take a different standard, and the result is that they make a very good showing. I would like to point out that these comparisons on paper of the upright board with the flat board have one disadvantage—that is, they assume that you may take anything from an upright position, place it in a flat position, and have similar conditions. We have only to consider what would be the difference to us if these diagrams were taken from the wall and placed on the table. We certainly could not see them as well. If you apply the same thing to that black-board, you will be getting very much nearer to the condition of things with

* *Institution Journal* part 115, vol. xxiv.

† British Patent Specification No. 13778, 28th Feb., 1888.

‡ British Patent Specification No. 9096, 1st June, 1889.

switch-boards. If anybody would try to cover that black-board with chalk marks when it is lying on the table, he would find it, I think, judging roughly from the size, impossible to do so. I want you to realise this fact—that the comparisons made by Vail & Seeley, the comparisons made by Jackson & Sinclair, and the comparisons made by Mr. Sinclair in his paper, are not founded on fact. They are based on a wrong assumption. Really, the controlling factor in this matter is not electricity at all; it is simply anatomy. If you will regard the hand as the extremity of a lever of which the shoulder is the fulcrum, you will see that in an upright position the hand can describe a complete circle, while in *that* (a horizontal) position it can describe only a semi-circle. The result of that applied to practice is that a multiple switch-board on the upright has double the capacity of a multiple switch-board on the flat. That is the essential governing factor of the whole business. If you will further consider the hand as a lever, and you will consider the application of power to that lever, you will find that in the upright you have a maximum of easy work, whilst on the flat you have a maximum of difficult work. If you strike straight from the shoulder you get the fullest power, and as you go away from the centre your power is gradually reduced. On the upright you have a majority of the power easily applied; on the flat the majority is applied under circumstances which mean that you have the weakest leverage. Of course we are not dealing with heavy weights; but where you have to make 200 connections an hour, and put in the plugs for that purpose, it means that there is an aggregate of work which counts in the day's work. Whilst the upright is easy the flat is difficult, and that results in increased cost of working; and when you get increased cost of working you have got to the crux of the matter. You may save in the cost of construction, but it is only at the expense of the cost of working; and of the two, the cost of working is the more important. Of course the wages is an important item in conducting a telephone exchange. There are two points here that Mr. Sinclair refers to as the most important which led him to adopt the flat-board system. One is, that in consequence of the smaller number of

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jacks and quantity of cables used, better speaking results are obtained and fewer faults occur. I am afraid Mr. Sinclair has in his mind an obsolete type of the multiple switch-board—the break-jack system, as in Fig. 5. It is a distinct drawback to multiples, because you introduce possible faulty contacts; that is to say, the dust may come in and troubles, generally, arise. That is a reason for not using that kind of apparatus at all. For metallic circuit work that apparatus is practically obsolete. When you come to use the branching system, which is described in Fig. 3, you have a condition of things in which you may multiply your jacks indefinitely, and not incur any real trouble in regard to the speaking results. You have two lines straight through the board. The only difference between those lines inside the room and outside the room is that you have a somewhat smaller conductor, and that you have it covered. The only trouble that may arise from it in talking is the trouble which may exist from the reduction of the conductivity and the increase in capacity in the small portion of the lines in the boards, and both those conditions you may regard as absolutely negligible quantities. Then the second reason Mr. Sinclair gives is the difficulty in finding room for upright boards, and the advantage of putting them on the flat, because they practically only take half the floor space required for the upright boards. If you take a multiple switch-board, placed under ordinary conditions, as usually used, round the room, with access to the back of the board, you will have a board with one operating face running on three or four sides of the room. If you have a multiple switch-board on the flat, you will have two operating faces for each row of switch-boards, but in no case do you double the capacity of your room. As a matter of fact, if you really want to get a large number of subscribers into a room, you must use the upright board. The reason of it you will see from taking Figs. 6 and 7. In Fig. 6 you will find the cable racks go down somewhat deeply into the board. As a matter of fact, in Fig. 6 the cable racks are less than one-half of the distance across the board. It is, if I remember rightly, 40 inches across and 17 inches down. If you put that upon edge, and another board of similar construction

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at the back of it, you have exactly the condition of things that exist there; but you will get your two rows in less ground space than with the flat board. The reason is, of course, that you have less ground space occupied by standing any object on its edge than by laying it flat. The difficulties of detail in working a multiple switch-board on the flat, in installing it or extending it, are such that I do not think it necessary, and I am sure, Mr. Chairman, you would not like me to do so, to go into them in detail. One thing I may refer to, however, is the question of operating. On one side of the board an operator will read the numbers in English fashion—from left to right; on the other side of the board the operator must necessarily read them in Arabic fashion—from right to left. It is difficult to change your operators from one side to the other. Then to come to the more practical question of the cost. The comparisons in the paper are made entirely on what I may call old types. It is a question of an operator attending 50 subscribers. The first multiple board that was introduced into England had one operator to 50 subscribers. Now we have boards made for 450 subscribers on the upright, worked by three operators. The board I refer to is a Western Electric branching board, and is installed in Christiania. At present it is not being worked to its full capacity, as there are trunk lines on it, and it is found a little too much for the operators. But boards of 360 are quite common. That gives 120 subscribers to one operator. It is the facility of working which makes this possible, and that really is the crux of the question. You must reduce your operating expenses, whilst taking care that the apparatus is retained, as Mr. Sinclair says, in the highest state of efficiency. You do it by using upright boards, by making them fast, by giving as many subscribers as you can to the operator, and thereby saving your working expenses.

[*Communicated May 7th.*]—I may perhaps be allowed to add to my spoken remarks that the Christiania board is fitted for about 5,000 subscribers, and takes about 55,000 jacks, instead of the 125,000 mentioned by Mr. Sinclair as necessary for that number of subscribers. In other words, the number of jacks on this upright board is about 7,000 less than they would be on the

r. ingsbury. flat board described in the paper; and, whilst the daily average of calls is about 50 per cent. more than those of Glasgow, the number of operators is 50 per cent. less than provided for by the author of the paper.

I should like to say that the suggestion to change the name of the "branching system" to that of the "self-restoring "system" is not likely to receive support. The word "branching" has the great merit of being short and yet describing the important feature of the system, which was devised with the object of avoiding contacts in jacks. "Self-restoring system" simply gives prominence to a feature which is of great advantage, but entirely subsidiary to the branched jack contacts. So far as I am aware, the word "branching" was first applied to the Western Electric system described in the paper, and I think it would be of interest for Mr. Sinclair to state when and how it had been previously used. I may add that in details the system described has been considerably altered and improved.

Attention should be drawn to the disadvantage attending the use of a three-conductor cord in the Fig. 5 plan of board. This plan was designed some years ago (I think by Scribner) for use as a trunk board only, in connection with what I have described as the "transition system" (*Journal*, part 115, vol. xxiv.). It was not largely used even as a trunk board, where, the number of cords being small, frequent testing for continuity is possible; whilst when placed throughout the exchange it would be much more difficult to anticipate faults. The three-conductor cord is thus a source of weakness, and of expense for renewals.—J. E. K.

Mr. Binswanger. Mr. G. Binswanger: I am very glad to see that Mr. Sinclair is adopting an independent line in telephonic exchange practice. He has given us in large centres like Manchester the flat board and the call system. I must say that, like many others, I have had my doubts as to how the public would take to the call system; but from experience I can endorse everything Mr. Sinclair has said upon the subject, and that in spite of the remarks of Mr. Kingsbury. We have had occasion in Manchester to use side by side both the call system and the annunciator system, and my own experience, and that of most of the sub-

scribers whom I have consulted, is that the call system is preferred. We feel that we are in more direct communication with the exchange and with the subscribers. We certainly get a much quicker service, which, after all, is the principal thing. This also shows that the subscribers do not mind the extra work imposed in the call system; and this fact leads in my mind to the question of whether we could not put still more work into the hands of the subscriber, and thereby reduce the work at the exchanges, making them more automatic. We have heard lately a good deal about automatic exchange systems both in England and in America. I understand that an automatic exchange system is actually in operation in several centres in America, having subscribers up to 200. No doubt Mr. Sinclair has investigated these automatic systems, and it would be extremely interesting and useful if we could hear from him what he thinks of them. I do not ask this question to know whether he would ever adopt them in his own exchanges—this I think hardly possible—but there can be no doubt that, if an automatic system of exchange could be devised which is both simple and reliable, it would be extremely useful in small exchanges, and especially in private exchanges, such as works and large establishments. The author in his paper referred several times to American practice and invention. No doubt most of the apparatus and appliances which we are using in telephony, and especially in exchanges, have come to us from America; and this fact might give the impression to outsiders that American telephone engineers are more ingenious or more enterprising than we are here in England. But we all know this is not the true explanation. The fact is simply this—that the first proprietors of telephone patents killed the industry in England in its early days. Those who, like myself, know the history of telephony, will agree with me, I believe, when I say that the first commercial telephones were made here in England. Mr. Preece brought Bell's first telephone to England, and demonstrated it here in public before it was generally known in America. The telephone industry in England sprang up quickly, and it looked as if the whole world were to have all their telephones from England; but the

Mr. Binswanger. proprietors of the master patents threw the industry into American hands. We therefore ought to be thankful that at the present moment there is at the head of the Telephone Company a man who will, and can, adopt an independent course; and we are indebted to Mr. Sinclair for the very opportune paper he has given us. He has shown us that he will emancipate himself from former practice; and in this wise alone can we manufacturers in England hope to regain the losses which we have had in telephone matters in England, as well as in our Colonies and abroad.

Mr. Preece. Mr. W. H. PREECE: In the first place, I should like to compliment the author, Mr. Sinclair, and his company. This is the first occasion on which any representative of the National Telephone Company in this country has had the boldness to come before this Institution and tell us what they are doing. Mr. Binswanger spoke rather strongly of the mode in which the industry in this country had been killed by the early promoters of this particular business, and I do not think that there is anybody who has ever spoken in severer terms of the management of the National Telephone Company than I have in this particular hall. Its management in the past was unquestionably execrable; but I am happy to say that a complete change has come over the spirit of their dreams in Cannon Row, and now we find this particular company, so obnoxious in the past, is doing all that it possibly can to repair the evil that has been done, and they are now working with an energy, spirit, and talent that in the course of perhaps a few months—certainly in a year or two—will bring the telephone industry in this country into a position that will compare with that of any other country, not even excepting America. It has been my good fortune to have seen, perhaps, more of the working of telephones than most people. I have spent a long time—twice I have been over to America; I have been to Norway, to Sweden, to Germany; and, in fact, wherever there was anything to be learned, there I have gone; and I find that the Telephone Company—I simply gather it from Mr. Sinclair's paper—is picking the cream of what has been done elsewhere, and we are all going to reap the benefit. In the first place, they are

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introducing metallic circuits, and you know how strong I feel on that matter. I have said over and over again that a telephone without a metallic circuit is an imperfect and incomplete apparatus. Any single-wire system is certainly deficient and defective. Gradually the Telephone Company are introducing metallic circuits everywhere. Again, they are introducing multiple boards. These multiple boards, of course, they are compelled to use with the growth of the system; but I disagree with Mr. Sinclair in this respect, as my opinion is that the day of the multiple board for large exchanges is over—I won't say quite over, but I think the multiple board is doomed. The experience in America is that as an exchange grows so do the difficulties of multiple boards, at a much greater rate. Their expense, as Mr. Sinclair has pointed out in the paper, grows in a terrific ratio, and there is a limit when unquestionably an exchange becomes too great for a multiple board. The experience in America, in Sweden, and in Berlin seems to be this—that when you get to 5,000 subscribers the difficulties are so great that they must be met in some other way. In the States and in Berlin they have been met by decentralisation. In Chicago a system which Mr. Sinclair has referred to, called the "divided board," has been inaugurated; but in San Francisco there is another system, called the "express system," which has also been introduced in Chicago and one or two other places; and there up to the present moment the reports received are so satisfactory that it would seem, sooner or later, the multiple board in all big exchanges must give place to something like the express system. I quite agree with Mr. Sinclair that in small exchanges of 2,000 or 3,000 subscribers nothing can be better than the multiple board. Mr. Sinclair in his paper has spoken a good deal on the question of trunk working and its difficulties. On that point I am not prepared to-night to speak. Only within this last week or two the Post Office has had transferred to it from the Telephone Company the whole of the trunk system in this country, and it will take some months, perhaps, before it can be thoroughly licked into shape; but I hope by the commencement of the next session that we shall have in this country the finest trunk

Mr. Preece. telephone system in the world. I think we shall commence the next session of the Institution with a paper written by Mr. Gavey, describing the trunk telephone system in this country, and how it has been worked. Mr. Kingsbury has criticised a good deal the observations that Mr. Sinclair has made on the call-wire, or what he calls the "Law," system The Law system worked on a large scale has its difficulties. I entirely object to the Law system, for the simple reason that it is absolutely unnecessary. In fact, I cannot understand, with the experience that you all have before you of the want of any call system or any manipulating mode at all of calling attention, why this system of calling, either by a magneto or by the Law system, is persisted in. We in the Post Office have never had such a system. Our call is automatic. A man, when he goes to his telephone and lifts his telephone off the switch-hook, attracts the attention of the exchange; and when he has finished his talk and replaces his telephone on the hook again, there is the "ring-off," or clearing signal. Both the call and the ring-off are absolutely automatic, and they are perfect in their action. They have only one objection, and that is a very strong objection with those who have not tried it—it is no objection at all with those who have tried it—and that is, that it involves the use of a continuous current. Now the idea of having a battery continuously running on a subscriber's line is like a red rag to a bull to the old telephone man, but to a new telephone man, and to the Post Office man, it has no fears at all; and I am happy to say, from the reports received from America, that they are introducing there a visual system which will have all the benefits of that which we have introduced in the Post Office. Mr. Kingsbury has also criticised Mr. Sinclair's views of flat boards, vertical boards, or pannels. I have an objection to flat boards. There is a certain amount of fascination in the appearance of a flat board. It is certainly attractive, and there is something about it that is enticing; but my objection to it is purely a practical one, viz., the difficulty that the engineer has to remove faults while the operators are at work, and the difficulty of making any changes during working hours behind the board. Now with a vertical

board there is absolutely no difficulty. The operators proceed in their ordinary way, and the engineer goes behind; he examines his contacts, and his springs, and his pieces, and he can alter, and change, and shift without anybody in front having the least idea that there is anybody behind. In the position shown in Fig. 7 it would be difficult and awkward, if not impossible, to make these changes except when work had ceased. There is one more point that I wish to urge, and it is this—that we may make our apparatus as perfect as the apparatus described to us by Mr. Sinclair, and as perfect as the apparatus that I have seen in use in Sweden and in Berlin. You may have operators as charming as the young lady in the diagram behind me, and also, perhaps, as adept in the manipulation of her plug and jack; but unless you have subscribers who are equally clever in the manipulation of their apparatus, unless you have subscribers who take an interest in the telephone work of their office, and unless you have subscribers who will co-operate with the Telephone Company, or the Post Office Department, or the State, or whatever it may be doing the work,—until you get mutual forbearance, mutual assistance and support from each side,—you will never get a satisfactory telephone working in this country. There is a great difference in the mode of working in different countries. There is a considerable difference in the mode of working in Sweden and in England, but there is also a strange difference between the working in London and in Berlin. I say without the slightest hesitation, there is no place that I have ever visited where the telephone work is better done than it is in Berlin, and we have it well done there on a system that is technically defective. It is a system consisting of a single wire; it is a system where they use practically obsolete apparatus; and yet there is the fact that in Berlin at the present moment the telephone work is better done than in any town that I have seen either in America or in Europe. The reason is this—that there is absolute co-operation between the subscriber and the operator, and that half the work is done by the subscriber. Here in London, and in most places, a subscriber calls; he is answered by the operator; he tells who is wanted; the operator calls, tests the subscriber wanted; he calls

Mr. Preece. the operator and puts him through; and there are two or three operations performed unnecessarily. Now in Berlin you call the exchange. You say, "Number 34;" and he simply says, "Please "call." He puts you through to 34, and you yourself, the subscriber, call the friend you want to talk to. You know what is going on: you know if the subscriber called has not attended to his call; you know if he has left his business in the hands of the office boy, and you know exactly everything going on; and you can bully the subscriber, apply your bad language to him, and spare the poor operator girl, who, in my experience, has always done her very best to do the service properly for you.

Mr. Addenbrooke. Mr. G. L. Addenbrooke: It is rather difficult to take up this matter in a proper way after the able speeches we have just listened to. In order to say what I have to, I must take the paper rather as a record of telephonic work in this country at the present day, than an attempt to go into very debatable ground, except, perhaps, in connection with the switch-board. I myself was connected with the United Telephone Company from early in 1883 to the end of 1886—nearly four years—and during that time I think the Telephone Company may be said to have got into shape. It was more or less a scramble up to that time; but the great problems which we are now all talking about may be said, I think, first to have become apparent about that date, and while connected with the company I certainly took a great deal of interest in working at them.

The first point we have to consider in the question of telephone service is this: We have two other services. First of all we have the postal service: that takes a certain time—12 or 14 hours—to get to most people in the United Kingdom. Next we have the telegraphic service, which, we will say, under favourable circumstances takes an hour in which to get a reply. Then we come to the telephone. Now I have always felt, and believe it is really a fact, speaking commercially as a user of telephones, that an extremely rapid service is of far less moment to the community in general and to commercial men than thoroughly good speaking. The question of whether you wait five minutes or ten minutes, or even a quarter of an hour, is of comparatively small moment

Mr. Adderbrooke

compared with being able to speak thoroughly well and hear every word when you are through. Owing to the kindness of Mr. Preece, I had the pleasure of speaking over the line to Paris when it was opened, and also over the line to Dublin; and, notwithstanding the great distance of those lines, and the fact that they were part of the way under water, the speaking was far better than on the majority of the company's lines about the country, which, perhaps, are not more than two miles long. It is true that a great deal of improvement has taken place in telephone work in London through the adoption of the double wire; but in the country it is generally lamentably behind what it might be. From my own experience, I must say that the telephone is really most important to people in the country. Where it is worth to a firm, we will say, £20 or £30 a year in London, it would be worth double or treble that amount in the country, if the service could be made what it is certainly capable of being made, from what we now know of the apparatus and construction of telephones. It is further worth mentioning that many of the difficulties which we are battling with in London do not occur in the country; it is possible we are just approaching them in Manchester, or perhaps in Glasgow. But take thirty millions out of the population of this country: they can be served by telephone by existing switchboards, and by arrangements that are all worked out, and which can be made to act very perfectly indeed, and no doubt would give immense satisfaction and be a great aid to business men in the commercial competition we are all engaged in with other countries. Supposing you are in some manufacturing district, and your works are two or three miles away from the nearest town, as is frequently the case, or even a mile away,—or, on the other hand, supposing you have a large scattered population, such as you have over Lancashire or in the Birmingham district, where the trunks are only a few miles long (we know that Mr. Preece can run trunks from one end of the country to the other, and we can speak perfectly well),—we ought to get a service over districts like that which would be so perfect that it would be almost like speaking to the next room; so that people who have factories, and get one thing from

Mr. Addenbrooke. one man, and another from another, or from railway companies and so on, could all be in perfect communication. For such a service as this it is not necessary to get through in half a minute: if you can get through in five minutes, it is all that is wanted, provided you can speak perfectly well when you have got through, so that you can always make yourself heard and get a clear answer. As regards the co-operation of subscribers, that is, no doubt, a very technical matter. I perfectly appreciate the position which the Telephone Company take up in this country, especially as regards London, because when you come to deal with a great many trunks you cannot get through without cross connections; and you cannot expect a subscriber to go through from trunk to trunk, as you might if the subscribers were all coming into one exchange.

I think Mr. Sinclair has hardly done justice to previous work in his few remarks at the latter end of his paper. It happens to be a matter upon which perhaps I can speak, as I had personal experience of it, although I can hardly be said to have taken any real part. He says he has found it is necessary to have a central trunk service in London. Of course that is literally true, but I think not quite in the manner in which people would gather from the paper. That trunk service was established at least 10 or 11 years ago, and as it forms, I believe, almost a distinctive feature of the London service in which the work is original, it is a very important matter, and of course it has attained very great dimensions. Perhaps I might relate a little bit of history. If I am not mistaken, it was towards the end of 1883 or beginning of 1884 that this question of trunk communication first began seriously to crop up, owing to the difficulty of getting through trunks to other exhanges—the eastern exchanges, and some of the exchanges in the City. The matter was debated for some time, and there was a meeting at the Euston Hotel. Mr. Morgan was managing director then. I think the company consisted of Mr. T. Fletcher, Mr. Phillips, Mr. Ashmore, Mr. Ullett, Mr. Clay, Mr. Hawes, and Mr. Addenbrooke, as far as I can recollect. How I got there I do not quite know, but somehow I was there; and, although

I took very little part in the discussion, I think I can speak of what took place, just because I did not take a prominent part. It was at that meeting that that trunk system was decided upon, and within a very few months it was put into practice; a board was designed by Mr. Hawes, somewhat on the system of the board on the table, to work it; and the London exchange system was really put down on the basis on which it has gone on since. Therefore I think it is only fair that some credit should be given to those who really did initiate that trunk service, almost precisely, as I gather, as it stands now. Mr. Addenbrooke.

Mr. F. B. O. HAWES: There are one or two points I should like to refer to. In the first place, however, I think we must congratulate Mr. Sinclair on having brought this subject before us. I am no longer connected with telephony; but feel there is a dearth of telephone papers at the Institution, and I hope we shall have many more of them. I think Mr. Sinclair might have given us a little more information about one or two points, and perhaps he will oblige us later on. At the present time in London call wires are used between the exchanges for working the junction wires, and I think it would be interesting if the author would tell us what proportion of junction wires those work on—that is to say, how many junction wires one call wire serves. Call wires were used in London telephone exchanges many years back for this purpose. At one time, however, their use was almost entirely abandoned, when multiple boards were beginning to be more generally used; but now I think they are being used again fairly universally between the larger exchanges. The other point is a small matter of detail which I think it will be useful and interesting for us to hear something about. I believe that in the exchanges the generators for the alternating ringing currents are driven by motors. It would be interesting if the author would tell us what motors he finds most serviceable. The next point I come to is with regard to flat boards. I must admit I do not agree with the points Mr. Sinclair has raised in their favour, and I think that my opinion is shared by the majority of telephone men in this country. The United Telephone Company were the first to use a multiple switch-board in England, Mr. Hawes.

Mr. Hawes. of a pattern designed by me, which was intended to be used in an upright position. I think it was at Mr. Clay's suggestion that we used it lying down. Mr. Sinclair says he does not quite understand why we should have used that board in that way. The reason was, however, that in those days we had no experience of how many subscribers one operator could attend to on a multiple board, and thought it better to err on the right side. By putting the board flat we provided for, if I remember rightly, one operator for each 25 subscribers. This, as it turned out, provided for more operators than were required, and experience showed that we could have worked those boards much better upright. Of course we must not entirely take *those* boards as an example of the difficulties of maintaining flat boards, as they were designed for being used upright. There were contacts which were seriously affected by dust; and, as was rather expected, there was trouble from that cause. We also had trouble about effecting repairs, and I cannot see how any flat board gets over those troubles. Telephone systems have to be worked constantly now; and, therefore, when repairs are necessary, they must be carried out while the switch-board is at work. A switch-board is started with a certain capacity, *i.e.*, with a certain number of jacks in it: when the number of subscribers has reached that limit new jacks have to be added; and the addition of those jacks is a very serious piece of work in a flat board, as it is next to impossible to see what you are doing, to say nothing of the difficulties under which the operating would be carried on while such an addition is being made.

Then we come to the question of the size of the board. Working on the figures Mr. Sinclair gives us, it appears that, with the switch-board on the flat system, a board for 6,000 subscribers would be one yard square. If you take a table a yard square and sit on one side, and then try to reach over to the opposite corners, you would find it almost impossible, if not quite impossible, to do so while sitting. I think you would have to stand up to the work. And naturally it does not help to expedite matters if the operator has to keep jumping out of her chair for a great proportion of calls.

Then there is another question with reference to flat boards which I should like Mr. Sinclair to tell us about from his experience, viz., the fact of the cords getting entangled as they come down on to the board. It certainly was our experience with our board. It would appear to me also that in pulling out one plug you would be very liable to pull out others with it. I should like to hear what the experience has been in that respect. Mr. Kingsbury referred to the dirt getting into flat boards, and that I think is another very serious matter. I would go further than Mr. Kingsbury, and say that, whatever sort of multiple board is used—whether you use the one shown on Fig. 5 or the one shown on Fig. 3—there would be leakage from line to line, and you would get a certain amount of cross talk, owing to soot and that sort of dirt, which is bound to accumulate. Mr Hawes

Mr. Sinclair refers to up and down trunk wires; I think, perhaps, more might have been said about them with advantage. At first sight, when you have a certain number of junction wires between two exchanges, it would appear to be most economical to use them irrespective of what class of call you put on—that is to say, whether it was from A exchange to B exchange, or from B to A. But when the details of the working are looked into, it is found that there is a great benefit obtained in dividing the wires in half, and using one half for calls in one direction and the other half for calls in the other direction, owing to the greater rapidity with which they can be worked. It is rather difficult to describe in detail why this is so; but this system, which I managed to get adopted originally, certainly has come to be now regularly adopted.

Talking of working rapidly brings me to Mr. Addenbrooke's remarks on the matter of quick working not being of great importance, which, I think, must be received with some caution. Even in London, I think if I had to wait five minutes for every call I should be very much annoyed. Good talking lines and instruments and rapid working are both essentials, and fortunately the former assists the latter. With what Mr. Addenbrooke said about the central junction exchange I entirely agree. That scheme was a very old idea in London,

Mr Hawes. and one which very many people claimed as their own. I was very glad when we managed to carry it into practice, as it proved of very great benefit to the system.

Mr. Preece referred to the express system in Chicago. In London we have something approaching the express system. The National Telephone Company have a small system at work for London stockbrokers only, which system, I have always heard from the users, is a very rapid one; and, as it is not worked in their name, it is held up to them very often as being an example of a perfectly worked exchange, by subscribers to the general system. That exchange, I believe, is still worked by very ancient apparatus which was discarded from the other exchanges; but it is merely the fact of there being no junction wires and only a comparatively few subscribers—about 400, I believe—that the service is so rapid. Then there is the question of the system of working, in which the subscriber does the work, of ringing up the person he wants, as Mr. Preece has told us is the system in Berlin. When a subscriber has a lot of work to do, ringing away all the time he is waiting, he does not notice the time going as much as when the operator is doing all the work for him. I believe myself that when the operator does the work, the time taken in getting through is much less on the average, but when you do the work yourself of ringing up the other subscriber the time goes unnoticed by you. The disadvantage I always feel about that system is that, supposing the connection is not made in the exchange, you may be ringing on until you are black in the face without producing the desired result.

Mr. Somerville. Mr. G. J. Somerville: Mr. Sinclair has mentioned as a weak feature of the American divided board that no connection is made without being dealt with by two operators. It is certainly a very weak feature of any board at which one operator cannot complete any connection asked for. This defect, however, is not altogether absent from the multiple switch-boards used generally in this country. We are informed that the length of each section of these boards is 6 feet 6 inches: it therefore follows that in the upright boards the operator is expected to stretch a distance of 3 feet 3 inches to either side of the point opposite which she sits, and this

Mr. Somerville.

ought to be done without inconvenience to her neighbours or interrupting their work. She might be able to accomplish it if she had plenty of freedom and elbow-room; but we have to remember that four operators are sitting in front of each section, so that the space allowed to each is only 19½ inches. In the case of the flat boards matters are even worse. We have been told to-night by one of the speakers that the width of these boards is about 40 inches: to make some connections on these boards the operator will therefore be called upon to insert a plug in a jack which, being on the opposite side of the board, is not less than 4 feet distant from where she is sitting. Taking into account the fact that in the flat boards eight operators are working at the same section, and that the plug and cord have to be passed between the other cords in use at the time, I think you will agree with me that the operation is nearly impossible. In practice the operator does not attempt it, but asks for and receives assistance in making nearly 25 per cent. of the connections required. So we find that the weak feature mentioned by Mr. Sinclair is not by any means absent from switch-boards in use in the National Telephone Company's exchanges. Reference has also been made to the listening keys. These are used to connect the operators' telephones to the subscribers' wires. Of course some means are necessary for this purpose, but those now universally used by the National Telephone Company are not good, as they are responsible for introducing into the system a very grave defect. With this key, which Mr. Sinclair has very well named the "listening key," the operator has the opportunity of overhearing any conversation which is carried on by the subscriber for whom she has made a connection, or, in fact, any conversation passing through the exchange. It is useless to say that it is never used for that purpose; it can be so used at all times, and is thus a source of one of the very worst defects which can exist in any exchange system, viz., the absence of privacy. It is also to this key, as at present used, that subscribers are indebted for those annoying interruptions by operators, and their continual questioning, "Have "you finished?" I was very much pleased to hear Mr. Sinclair say that he is an advocate of the flat boards and the call-wire

Mr. Somerville. system; however, judging from results, I should imagine that until quite recently his advocacy must have been of a very mild type. Referring to the call-wire systems, I take it that it is the Mann system which is being introduced into the National exchange at Manchester. It is very interesting to hear Mr. Sinclair praise this system as he does, and I have no doubt, by-and-by, that he will advocate its use even in London. His objection to its being introduced here is without foundation. The real difficulty is in connection with the static capacity of the signal wires. That, however, can be overcome; and there is no reason whatever why the operator at King's Cross, when desiring to communicate with Lime Street, should have to do either of two things which Mr. Sinclair says are inevitable—viz., to cut herself off from the call wire, or to join her call wire, with its 50 subscribers, to the call wire to the City.

Mr. Sinclair. Mr. Dane Sinclair, in reply, said: Some of us are in the habit of sitting and listening to speeches and sometimes wishing they were shorter; to-night I am in that very comfortable position of being able to say I was not sorry they were so long. See how it has relieved me! The clock almost points to the hour when we must cease, and if all the questions are not thoroughly replied to, you must blame your own long speeches or the shortness of the time at my disposal. My friend Mr. Kingsbury, with his usual ability, has put his case so ably that I almost begin to doubt myself—and that is saying a good deal! It is really impossible to deal with all the notes I have put down; but I will do so with a few of them. While I advocate the use of the call wire under certain circumstances, Mr. Kingsbury condemns it altogether; and if he took his opinion of it from the Law system as it was fitted up by American experts in Glasgow, I do not wonder at it. When I joined telephone work first in Glasgow, the Law system was at work there with 200 or 300 subscribers, and it gave so much trouble that within six or eight months after that time we had to turn it out. In this, however, as in all other things, we must look for development. There came along, after it was further looked into, a modification of the system, and this has been referred to by the last speaker as the "Mann" system. That,

I think, as is the case with many inventions, was put in by Mr. Mann (at Dundee) without his knowing that it had been previously tried on the other side of the Atlantic. This does not detract from the value of the thing, but the modification makes a very great difference—indeed, all the difference between comparative failure and success. The difference is really this—that with the Law system, as I first saw it in use, each subscriber desiring a connection had to join his telephone in series in the call wire, and when finished, had to bring his switch back to the central position. If he failed to do this accurately, he broke the call-wire circuit, and so prevented the other subscribers on that circuit from communicating with the exchange. When the change was made to the "branching" call wire, where one or 20 may tap on, but where one has not the power to cut the others off, then came the difference. When a new exchange for Glasgow had to be considered, the question of call-wire working was fully gone into; and at a meeting of experts called from all parts of the country it was laid down that where you had an exchange with only a local system—that is, with no junction or trunk wires—then the call wire gave a perfect service. Therefore, in an exchange that has a very large proportion of local work, you get the advantages without the disadvantages; and, after all that has been said against it, I still think that is right. It is noticeable that in the discussion which followed the reading of my paper only one gentleman spoke who had had actual experience of both systems, and he, as well as his friends, preferred the call wire. This only bears out the opinion expressed by 95 per cent. of our subscribers in Glasgow. With regard to Mr. Kingsbury's remarks in reference to flat boards, there is really not time to go fully into that. Mr. Kingsbury ingeniously described how it was possible for a girl to take a complete circle with the upright board while she could not do it with the flat. But a girl does not take a complete circle. She cannot work at her back, or below the key shelf. It is merely a question whether she should lean forward or only move her arm forward. When this question was being discussed by the expe[illegible] of the company, a table was formed on a hinge, and a gent[illegible]

Mr. Sincl[illegible]

Mr. Sinclair was set at it, the point to be proved being, whether he could reach higher when the table top was vertical, or farther when it was horizontal. He could reach farther on the flat when he sat still, both to the right hand and to the left hand. He could not reach quite as far when the board was vertically in front of him. I was watching the gentlemen employed in making the calculation, and I came to the conclusion that there is nothing so serious in it as to make it a question worthy of grave consideration. Then Mr. Kingsbury gives another reason why flat boards are not as good as the upright—namely, the difficulties of wiring. I suppose there are difficulties. I have yet to live to see the switch-board with which difficulties are not connected. Therefore, it is a choice between a series of difficulties in one case and in another. One speaker has said it would be a very serious matter to increase the number of jacks on a flat board, because it would have to be done when it was at work. But it is not necessary to do it when it is at work: the jacks are previously attached to the cables, and a few hours' work in the evening suffices for fixing them in their places. With regard to the boards which we have in use to-day, it is a more simple matter to lift a row of jacks out of their place on the flat board than on the upright. I am now getting on to the point referred to by Mr. Preece, viz., that it is difficult for a man to get down among the wires to work. It is difficult, but it is not impossible; and in the course of instruction that our telephone engineers have to go through, we impress on our men the duty of behaving with propriety, even when in proximity to the opposite sex. Mr. Binswanger referred to one or two points, and he has given you the crux of the situation that had a good deal to do with our deciding whether to use the call wire with flat boards or not. We put it into Glasgow without being able to get any other opinion than that which was within ourselves; but when it came to the case of deciding at Manchester, we thought it would be a gracious thing to the subscribers, and an experience that would be worth having, if we asked the Glasgow subscribers whether they preferred the system they had before or the call-wire system. As I have said in my paper, 95 per cent. preferred *the call-wire* system. Mr. Kingsbury referred to the fact that

there were fewer calls on Glasgow with the flat board than there Mr. Sinc were on Manchester. This, however, was explained in the evidence given before the House of Commons. A general order had been sent out from the head office to take a record of calls at certain places on a specified day; and it so happened that the figures given occurred during the holiday season in Glasgow, and therefore were much below the average. Long before I left Glasgow the calls were very much more than the six mentioned by Mr. Kingsbury. With the old boards they were about 10, and my impression is that to-day they are something like 13. Of course I am now speaking from memory, but I am not far away from the truth. That does not bring them up to Manchester, and Liverpool is higher than either. Mr. Preece's remarks come with such weight and force that it makes one think twice before knowing how to reply to them. We all know he has advocated—and rightly advocated—the use of metallic circuit wires from the inception of telephony, and I think it is a great credit to him that he was so early a champion of a good cause. It would be perhaps irrelevant for me to enter into all the *pros* and *cons* which led the telephone companies to decide what was best. The engineering question was not the only one to consider: there was the commercial element as well as the engineering; and I am not going to say that I ever knew of a telephone company in this country which did not encourage its engineers in every way to give an absolutely good and perfect service. When it came to metallic circuiting, that was a very large and involved question. We are metallic circuiting to-day in Manchester; but why? Because the Corporation has invited us to go underground; and we are putting down a system which we believe will be there as long as we care about. When other cities invite us to do the same thing, you may all guess what will be likely to happen. When Mr. Preece goes on to describe the beautiful service in Berlin, he just quotes the very reason why I like the call wire. It throws the responsibility and the actual work off the hands of the operator and into the hands of each individual subscriber, but with this difference, however—that if the subscriber who is called up does not reply, the caller gets an explanation from the exchange of the reason; that is

Mr. Sinclair. say, he is assured that he has been properly connected; and this in itself is, I believe, the greatest reason for the success of the call wire. When we compare the battery system with the call-wire or the magneto ringing system, it is true that the battery system appears to be perfect so far as sending a signal to the exchange is concerned (if expense is not considered); but the point is that, so far as I know, there has never been any difficulty with the magneto system in giving an instantaneous signal at the exchange. Therefore, as between the battery system and the magneto system, it is only a choice of which works best; and as we have Manchester still working on the battery system, and as this system was previously in use at Glasgow and London, where we now have the magneto, we have had good opportunities of comparing the working of the two systems, and our experience is that a signal with a magneto is much more reliable than with a battery. The main point, however, is that, although a signal, as immediate and perfect as the automatic signal used by the Post Office, can be sent from a battery or magneto to the operator at the exchange, it does not follow that that signal will be obeyed by the operator, or that her reply will be immediate. On the other hand, on the call-wire system the subscriber commands the situation, and receives an immediate reply from the operator, whether she likes it or not.

One speaker has referred to the central trunk exchange in London. I suppose we all know that a great many people thought they had invented that system. But, although the system was a good one in itself, it was thought too much of, and, like many another good system, was carried too far, and we actually in practice have had to undo a great deal of it. What we found was this: If you take two small exchanges in the suburbs of London, the wires must run into some centre point where they can be joined on to any other branch exchange; but if you take two large exchanges, one in the West End, as Gerard Street is now, and the other in the City, as Lime Street is, and if there are 20,000 calls per day through these two exchanges, will any engineer explain to me what is to be gained by putting all these calls through a third or central exchange? It was found,

when looked into, that we wanted the central trunk exchange for overflow work, and to take wires from all the branch exchanges that cannot afford to have direct junction wires to every other. And that is the system that is being worked out in London to-day. This is a much more serious part of the service than one might expect. I think I have said in my paper that if an exchange has 40 messages per day from it to any other exchange, it is provided with direct junction wires; but if fewer than that, the calls go through the central. I am afraid, gentlemen, that you will really have to take the will for the deed, and accept these few unconnected and rambling remarks as replies to your able and considerate criticisms. Mr. Sincla

With regard to the communicated remarks of Mr. Kingsbury, it may be well to add that the number of jacks I mentioned in my paper refers to what has actually taken place in this country. Four operators for each 200 subscribers was taken in making my calculations, this being the basis in use for the branching system, both on the ordinary upright and on flat boards, as well as on the ordinary make-and-break system; and, therefore, the comparison made in my paper I consider is the correct one, especially as the facts in actual practice are as I have stated.

Whether this method of working should be known as the "self-restoring" or the "branching" system, is of very little importance. My reason for preferring the term "self-restoring" is that it conveys the idea of what is claimed to be new; but the term "branching" is misleading, as the use of the branching system in telephone work is nearly as old as the telephone industry itself, and the Government exchanges at Newcastle and elsewhere have been always worked on this system.

With regard to the three-conductor cord system, it is merely a question of using a three-way cord, or of having a "make-and-break" contact in the test wire at every jack throughout the exchange. We have had a great deal of trouble with the "make-and-break" in many of our exchanges, and the three-way cord was introduced as it was considered that it might give less trouble than had arisen from the contacts. I am free to

Mr. Sinclair. admit, however, that, now that greatly improved jacks, as made in Stockholm, have been put into use, the trouble of the "make-"and-break" in the test wire has been considerably lessened, and I believe that in future we shall return to the use of the two-way cords.

Sir Henry Mance. The CHAIRMAN: I am sure we are all very much obliged to Mr. Sinclair for his interesting reply to a very interesting discussion. One of the most satisfactory points we have heard mentioned is, I think, the rapid increase in the metallic circuit. This must be especially interesting to those electrical engineers who are connected with electrical tramways. This paper has been devoted almost exclusively to the consideration of the various forms of switch-boards used in telephone exchanges. I trust that when the promised paper by Mr. Gavey is given to us next session he will deal with the disturbances which are observed in telephonic lines when electric tramways are worked in their vicinity. Prevention is better than cure, and it would be most desirable to have on record past experience which might give us some rule by which electrical engineers can work, so as to avoid causing any disturbance in the adjoining circuits.

I have to announce that the whole of the candidates up for ballot this evening have been elected.

Associates:

Stanley J. Goddard.
William Johnson.
Walter Victor Morten.
Robert Ellis Shawcross.
Arnold Turner.
Ernest Anthony Max Winter.

Students:

Edward Nugent Bankes.
Sidney John Clay.
Benjamin Shuttleworth Hornby.
Charles H Rosoman.
Ralph Rushton, jun.
Bernard Sankey.
Percy Cunliffe Simpson.
William George Stuart.
Frank Triste Woodley.

The meeting then adjourned.

The Two Hundred and Eighty-ninth Ordinary General Meeting of the Institution was held at the Institution of Civil Engineers, 25, Great George Street, Westminster, on Thursday evening, April 30th, 1896—Dr. JOHN HOPKINSON, President, in the Chair.

The minutes of the Ordinary General Meeting held on April 16th were read and approved.

The names of new candidates for election into the Institution were announced and ordered to be suspended.

The following transfers were announced as having been approved by the Council:—

From the class of Associates to that of Members—

George Keith Buller Elphinstone. | Robert Willsher Weekes.

From the class of Students to that of Associates—

Joseph Henry Draper Brearley.	Frederick Augustus Leigh.
John Hayton Carrick.	Hugh Bernard Maxwell.
Percy Rhodes Cobb.	William Samuel Parsons.
Hugh Capper Crawhall.	James Toulmin.
Sidney Phillips Doudney.	Howard Stanley West.

Mr. J. H. Reeves and Mr. Max Binswanger were appointed scrutineers of the ballot for new members.

The PRESIDENT: We have only three more meetings this session, and we have three important papers to get through. It therefore becomes necessary that in each evening we shall complete the discussion on one paper. We must, therefore, in any case complete the discussion on Mr. Langdon's paper this evening; and with regard to the remarks of gentlemen for which there is not time, we must ask them to contribute them in writing, so that they may appear upon the minutes. I will call upon Mr. Langdon to read his paper.

ON RAILWAY TELEGRAPHS, WITH SPECIAL REFERENCE TO RECENT IMPROVEMENTS.

By W. Langdon, Member.

Mr. Langdon.

The subject with which this paper deals is one which has not, for some time, claimed the consideration of members of this Institution. The progress which has attended the application of electricity to railway telegraph work is in no way comparable with that which has in recent years marked its progress in relation to lighting and power. Such advances as have been achieved are to be found more in minor details than in any radical change. Probably the most noticeable fact presides in the greater freedom from serious breaksdown which we now enjoy, and in the growth of the telegraph service—a striking testimony of its increasing utility. Competition is a stern and exacting master. The train service of to-day must not only be well equipped, but it must work well to time. That which yesterday was thought ample, is to-day found wanting. Each day ushers in fresh demands, greater elaboration, greater exactitude! How useful a factor the telegraph becomes in enabling this to be accomplished is probably known only to those in whose hands rests the responsibity of that which has to be done.

In the year 1880* the late Mr. Edward Graves, one of our Past-Presidents, and for many years our Honorary Treasurer, brought under the notice of members some extremely interesting statistics in relation to the progress of telegraphy, in which he produced a comparison between the mileage of wire and the number of instruments in use on the various railways in Great Britain in 1869 and 1879.

By the courtesy of the controlling officers of practically the entire railway service of the country—to whom my acknowledgments are gratefully tendered—I am, with the exception of the data of some two or three of the minor companies, enabled to bring forward this information another decade and a half.

* Vol. ix., p. 249.

Accepting Mr. Graves's figures as a basis, and making allowance for the expansion of those systems the returns for which are not to hand, we get the following approximate results:— Mr. Langdon.

		Miles.	Increase.
Mileage of wire employed for railway purposes ...	1869	27,204	—
	1879	62,099	34,895
	1889	84,423	22,324
	1894	99,296	14,873
		Instruments.	Increase.
Number of instruments employed for railway purposes	1869	10,121	—
	1879	46,847	36,726
	1889	100,590	53,743
	1894	130,339	29,749

It will be understood that these figures are not put forward as absolutely correct; they may, however, be accepted as fairly representative, and as a very near index of the progress and increasing influence of the telegraph service.

Prior to 1870 block signalling was but sparsely employed. During the decade 1869–79 it met with general adoption, which accounts for the large increase in both instruments and wire during that period. The increase during the half-decade 1894 is, in relation to that of the preceding decade, remarkable, as indicating that the expansion is still in active operation. These figures tell their own tale of utility in the management and regulation of railway traffic; while, from the mileage of wire maintained by the railways for the Postmaster-General, amounting approximately to some 67,000 miles, it may be reasonably inferred that the railways are in no small degree contributing to the convenience of that branch of the public who, from day to day, seek the service of the Post Office wires. Let us pause but a moment to consider how the present enormous traffic of our railways, or the mass of matter which daily passes over the various telegraph services of the country, could possibly be dealt with without these aids, or how the conditions of commercial life would be affected by their cessation, and we at once become sensible of their value.

Individually, possibly few railways afford a more forcible illustration of the rapid growth of a railway telegraph service than

Mr. Langdon. that to which the author is attached. In 1878 the total mileage of wire on the line amounted to 9,816 miles, and the number of instruments to 7,702. The mileage of wire to-day exceeds 22,000, and the number of instruments closely approximates to 19,000.

This large expansion is naturally calling for increasing accommodation for wires, and, in the interest of economy, for a careful study of the cost in both construction and maintenance.

Poles.

One of the chief factors to which we are indebted for the greater stability of our lines of telegraph at the present time is the employment of poles which have been charged to a certain extent with creosote.

In the session of 1873–74 a paper,* "On the Preservation of "Telegraph Poles," was read before this Institution, then the Society of Telegraph Engineers, in which the various processes for the preservation of timber were discussed. Of the several methods there referred to, the creosoting process may be regarded as the sole survivor.

Creosoted poles are now almost universally employed. Their life, or the period they may remain in position without deterioration from decay, is still, to all intents and purposes, undetermined. Given a properly seasoned pole, fairly dry when placed under the process, its life may reasonably be relied upon to cover the period the pole is required to stand before additions or alterations call for its replacement.

It is neither necessary nor desirable that the timber of telegraph poles should be completely charged with creosote. The quantity of creosote impressed into telegraph poles is usually 8 lbs. to the cube foot of timber; and this quantity, where the wood is properly seasoned and well dried, will be found to have penetrated to the core or heart-wood of the pole. It will thus form a complete protective shell, impervious to moisture; and in this lies the main advantage of the application.

Timber which is thoroughly impregnated or saturated with creosote becomes, as soon as the oil is dissipated, devoid of much

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* *Jour. Inst. Elec. Engrs.*, vol. iii., p. 181

of its elasticity, and is then more easily broken than if the heart-wood of the timber is allowed to remain uncreosoted. Mr. Langdon.

There are points where creosoted poles are objectionable—such, for instance, as station platforms. Here, whereas in former years Memel timber was usually employed, it is preferable to use pitch pine. Pitch pine is more durable than Memel. It is more resinous, and thus more antagonistic to the reception of moisture; and it is the moisture which, traversing the fibre of that portion of the timber in the soil, under the influence of the warmer atmosphere above the ground line, disintegrates it at, or about, the ground level, and so destroys it.

The number of wires which have now to be accommodated, in many instances, call, not merely for stout poles, but for structures, such as "H" poles. These structures (Fig. 1) consist of two poles, A, B, braced together at the foot by a slab of wood, C, as nearly as possible at right angles to the poles, and a further slab, D, some 4 feet from the butt end of the poles, arranged diagonally; the arms, E, at the top of the poles act as the tie-pieces at that end of the structure. These are sometimes, especially in high poles, supplemented by a stiff iron rod, F, passing through the two poles, at right angles to them, or by rods, crossing one another diagonally, tied together in the centre.

"H" Pole.

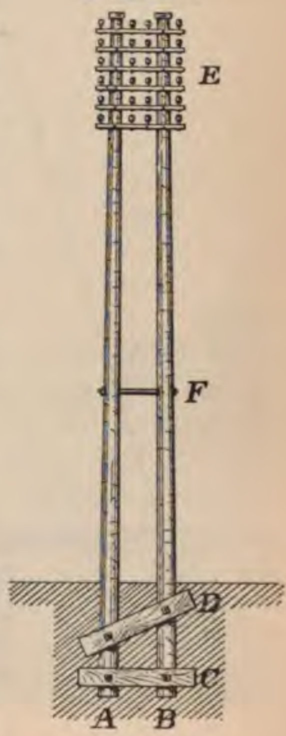

Fig: 1.

The practice has been to allow the two poles forming the basis of this structure to have a slight spread at their butt ends; *i.e.*, taking a centre line down the poles, the distance between these lines at the top of the poles being some 12 inches less than that *between the* centre lines at their butt ends.

Mr. Langdon.

When poles become crowded with wires, this, with respect to the lower arms, detracts from the regularity of the insulators and wires. It is better that the poles should be equi-distant throughout. You have then merely to provide for the increasing thickness of the timber in order to ensure perfect regularity in the position of the wires from top to bottom.

The Midland Railway having recently been called upon to construct for the Postmaster-General a section of an important trunk line to Scotland, it has been necessary to convert an existing line of single poles into an H line. To construct these H poles, braced together at the foot, as shown in Fig. 1, would have meant the replacement of the entire line—a most expensive operation.

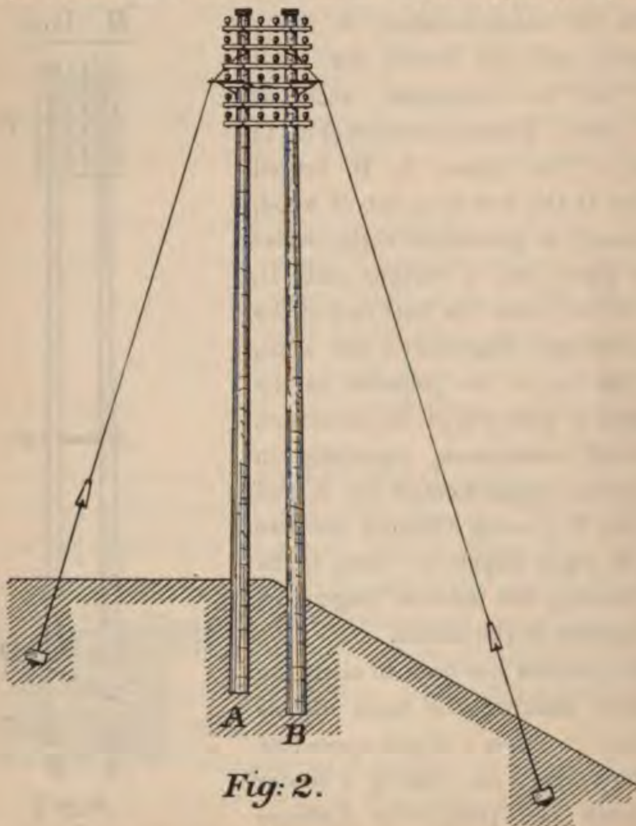

Fig: 2.

Under these circumstances the existing line of poles has been allowed to stand. At the proper distance a pole, B (Fig. 2), to

match the standing pole, A, has been placed in position, care being taken to cut off the butt end so as to ensure a flat basis. It has then been allowed to stand some days, so as to become well settled in its position, after which slots for the arms are cut to correspond with those on the original pole. The short arms are then, one by one, removed from the latter, and replaced by arms 56 inches long, which are bolted to the two poles. Where the old line of poles has been systematically constructed, with the arms, Mr. Langdon.

say, 12 inches apart, centre to centre, the appearance of such a combination is in every way agreeable to the eye.

Mr. Langdon.

It will be evident that without the diagonal tie-piece the poles might, under stress of wind, work themselves out of position. This has to be met by staying them in the same manner as a single line. Where, from exceptional causes, the poles cannot be stayed, the diagonal tie-piece should be employed. Photographs of sections of the line of poles thus treated are on the table.

H poles are destined to be of great service. There is no reason why the number of wires should be limited to four on an arm. The 56-inch arm may be replaced by a 72-inch arm, accommodating six wires, thereby increasing the capacity of the poles one-third. We may even venture beyond this where the need for it exists, employing either iron arms, or wooden arms of larger scantling, in order to meet the weight of the wires standing on the outer side of the poles. The structure is one which, if well stayed, will withstand gales far better than single poles with half the number of wires, arranged two on an arm.

Moreover, it will be observed that H poles, with six wires on an arm, lend themselves to telephone requirements. With the wires arranged two outside each pole, and two between the poles, three groups, or squares, may be formed by each pair of arms—each wire of each "square," or "group," being maintained 1 foot apart.

Telegraph poles seldom commend themselves to the observer as an æsthetical subject; but uniformity in construction, with the poles well in line, or regularly following the contour of the road, evenly graduated for height, and uniformly armed and wired, with, perhaps, an ornamental top in exceptional places, will do much towards removing those objections which are not unfrequently raised against their presence.

Arms.

In the trimming of poles the most novel feature is the introduction of iron arms.

Forty-inch tubular iron arms, specimens of which are before the meeting, have been employed for some 100 miles of the trunk telephone line recently erected by the Midland for the Postmaster-General. Some years prior to this shorter

arms—tubular and rectangular, for carrying two wires—were experimentally employed by the author. No inconvenience whatever has, so far, attended their employment. Mr. Langdon.

40 inch Iron Arm.

Fig: 3.

The longer (40-inch) arm (Fig. 3) is composed of $1\frac{3}{4}$-inch galvanised iron tubing, A, $\frac{1}{8}$ inch thick, strengthened by a piece of larger gauge tubing, B, of same thickness, 2 inches in diameter, carried over the centre portion of the $1\frac{3}{4}$-inch tubing. The two tubes thus combined are practically homogeneous and very strong.

The employment of these arms admits of a slight reduction in the length of the insulator bolt, which may, with advantage, have the shoulder of the bolt, as also the washer, hollowed out to fit the arm. Thus arranged, there is no possibility of the insulator twisting round. These arms should be very durable, and it is worthy of remark that they do not require so much of the pole cut away as is necessary for the wooden arm.

The earth-wiring of wooden arms has, the author believes, in some quarters, been abandoned. That course has not been pursued on the Midland. Earth-wiring, as illustrated by the sample placed upon the table, is still followed. With iron arms the need for earth-wiring disappears. It is merely necessary to lay the main earth wire securely under the washer of the arm bolt.

Clearly, where iron arms are employed, failure in insulation such as that produced by a broken or cracked insulator will readily make itself known. To what extent this will operate with respect to the iron arms experience must show. In a trunk telephone line discrepancies in the insulation of the four wires forming a square would appear to be undesirable factors. Whether such failure may be more readily traced with iron than with wooden arms has yet to be proved. The iron arms ought, where

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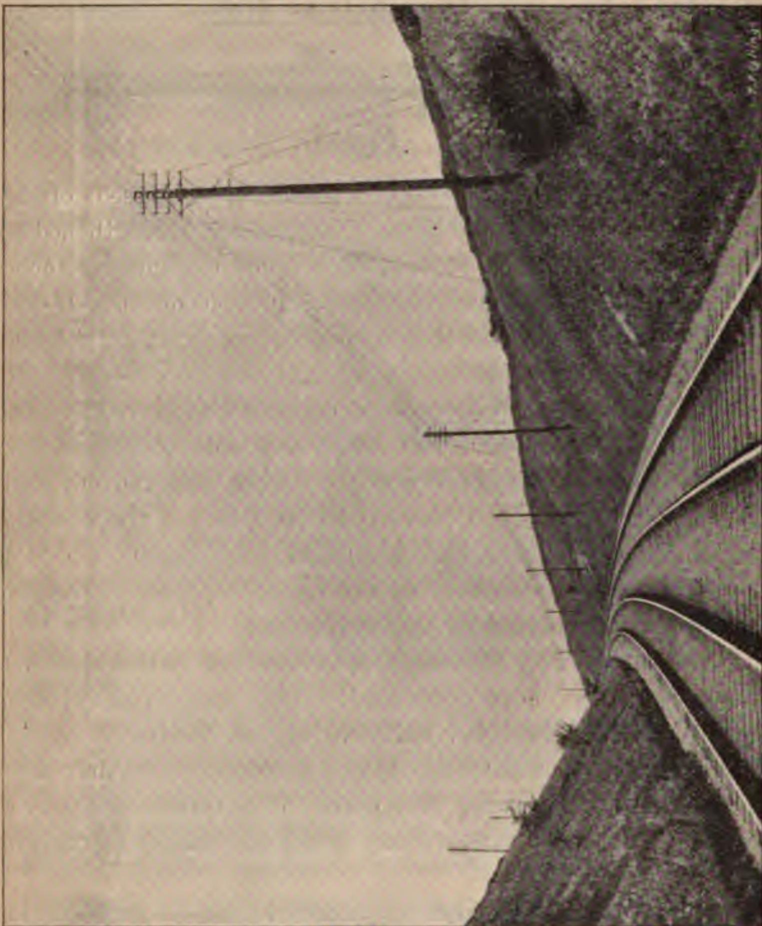
"earth" is the cause of failure, to give a more defined fault, and thus lead to its more ready removal. Iron arms and brackets, as well as iron poles, have, in various forms, been in use for years,



especially for foreign lines; and probably no member of the Institution has a more intimate knowledge of their value than our Past-President, Mr. Alexander Siemens.

In slotting round poles for these iron arms it was at first thought that a V-shaped cut would readily lend itself to the *reception* of the arm; but experience has shown that it is better

to slightly slot the pole, as though for a rectangular arm, and gouge out the base of the slot. The pole being round, the V-shaped cut fails to retain the arm in that rectangular position, in relation to the pole, which is necessary to give the line that trim and uniform appearance so acceptable to a good workman. Mr. Langdon.

In the employment of wooden arms there is nothing of a novel character to record. They are to-day very much as they have been during the last 20 years. It may not, however, be inopportune to raise the question whether English oak is the only timber from which they should be made. Doubtless English oak is more durable and stronger than other timber; but it is a question whether foreign oak—say Stettin—if cut under the conditions applicable to English oak, viz., well seasoned, free from knots, and free from sap, is not sufficiently durable and strong for the purpose. Arms cut from this description of timber have been in use on the Midland system for many years, and nothing has transpired to create a want of confidence in its suitability for such work.

Another point worth considering is that of painting the arms. Paint, if applied when the timber is properly seasoned and dry, is, no doubt, beneficial; but paint applied to wood which does not possess these qualifications produces dry rot, and is, consequently, absolutely injurious to the timber, and dangerous to workmen when on the poles. Where the arms can be stacked by the user until thoroughly seasoned, they may with advantage be painted.

Staying.

It is no exaggeration to say that to the more perfect manner of staying the telegraph lines of the present day, and to the employment of machine-stranded staying wire, are we indebted for that greater immunity from heavy breaksdown which we enjoy at the present time. It is, in cases of snow, falling under those conditions which cause it to cling to the wires, a question of strength of pole *versus* strength of wire. Needless to say it is preferable the wires, rather than the poles, should suffer; and, as a rule, such is the *status* at which well-built telegraph lines of the present day have arrived.

Mr. Langdon.

On railways there is usually more room for staying poles than is the case on roads. The greater the spread of the stay the greater its advantage. In order to be of the greatest service its attachment to the pole should be somewhat above the centre of the full complement of wires which the pole is designed to carry. It is seldom, however, one can determine the number of wires which a line shall ultimately support, and thus it is well to fix that point which may be most serviceable under any condition. The practice pursued by the author has been to fix the upper stay between the third and fourth arm, and where a second stay is required—as is frequently the case with heavily wired lines—between the eighth and ninth.

Formerly the practice was to form the stay on the pole, wire by wire. A single wire was first attached to the pole and strained up tightly to the stay-rod; then a second wire was attached and strained up, as nearly as could be judged, to the same degree of tension; and so on, till the necessary strength was attained. The objection to such stays is the absolute improbability of so arranging the several wires of which the stay is composed, that each shall bear its share of the strain. As a rule the strain falls upon one wire more than another. Under great stress this wire is the first to give way. The rest follow in like manner.

With machine-stranded staying wire, each wire bears its own proportion. If properly stranded—*i.e.*, with a long lay—it is easily handled. Where attached to the stay-rod it should be passed around a pear-shaped eyelet. To Mr. W. H. Preece, C.B., F.R.S., Past-President, we are indebted for the introduction of machine-stranded wire for this purpose. Staying wire should be of a steely character. The Midland specification provides that each No. 8 gauge wire (which is the only gauge used for stranded staying wire) shall stand a strain of 1,800 lbs., with a maximum stretch of 4 per cent., without breaking, and that it shall bear 12 twists in a length of 6 inches without fracture and without scaling.

An excellent device for binding stranded stay-wire has recently been introduced by Mr. Roberts, of the Postal Telegraph Department, which enables the workman to accomplish his task well and with ease. The tool itself will be found upon the table.

The strand wire is first bent so as to form the loop around the stay thimble, A (Fig. 4), the splicing tool, B, being employed to Mr. Langdon.

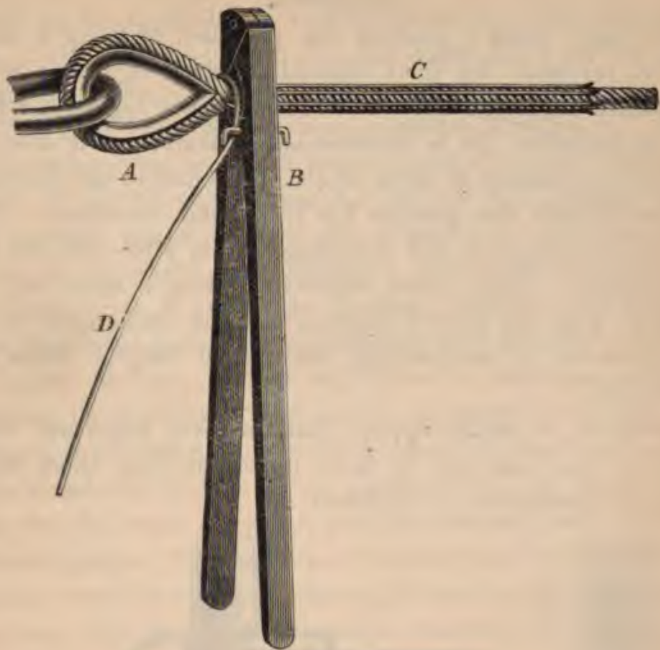


Fig. 4.

draw it closely into the groove. The free end of the stay-wire is then unstranded and the wires straightened out, as shown at C. One wire, D, is picked out for the purpose of forming the first lap of the binding; the tool is then employed to arrange the remaining wires symmetrically parallel with and around the main strand, so that they may bind into it without spoiling its circular shape. The free wire is now placed under the hook of the stay tool, which is revolved around the stay and the remainder of the wires. When the first selected wire has been used up another is chosen, and the same course followed with each until all have been evenly bound around the main stay.

All stay-rods planted in soil formed of cinders or ashes should be protected by fillets of creosoted wood, or they will rapidly succumb to the electrolytical action set up by the ashes and the

Mr. Langdon. galvanised iron. On railways it frequently happens that the top ballast is composed entirely of refuse cinders or ashes.

Insulation.

For many years a practice has prevailed of using a minor form of insulator for short circuits or block signalling wires. The author raises the question whether such a degree of refinement is desirable. It is inconvenient, inasmuch as it does not admit of interchange of wires where such changes are desirable. On the Midland the practice has long been abandoned. But one class of insulator, and one gauge of iron wire—viz., No. 8—is employed. Thus, when required, through wires may be joined in with the shorter lengths, and the uniformity of the line preserved by maintaining the shorter lengths below the longer ones.

Moreover, it would appear that, however important other wires may be, none can be more important than those which govern the movements of the trains.

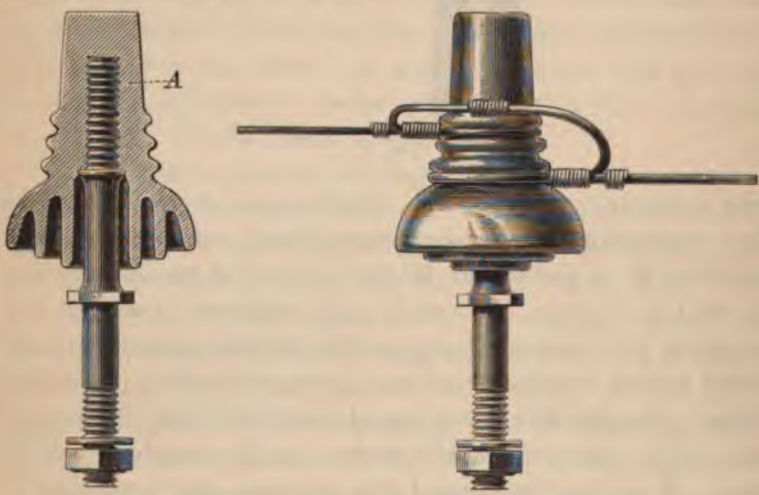


Fig. 5.

It is believed that the best insulators are those known as the "Post Office" and the "corrugated;" samples of which are on the table.

Samples of the form of terminal insulator and leading-in

cup, employed largely by others as well as by the author, are also before the meeting. The terminal insulator is made in two sizes, the smaller kind being employed where the strain is small, as, for instance, for leading across from one side of the line to the other for signal box and other like purposes. The larger kind is employed for terminations of line wires. Mr. Langdon.

The great advantage of this insulator presides, not merely in the shape of the ware, but in the extent of the bolt, A (Fig. 5), which, it will be seen, passes far beyond the corrugations at which point the line wires are attached—a provision which renders it practically impossible for a wire to fall, even when the porcelain is from any cause broken. Another advantage is that these corrugations, or grooves, not only help the insulation, but make provision for the attachment of different gauges or different descriptions of wire, as, for instance, if it is desired to attach a No. 11 to a No. 8. If the No. 8 is placed in the lower groove, and the No. 11 in the upper groove, the strain on the bolt will be about equalised, and the insulator will retain its vertical position. They are equally useful for joining two descriptions of wire, say iron and copper, the one being terminated on one ring, and the other on another, the two wires being joined by a loop.

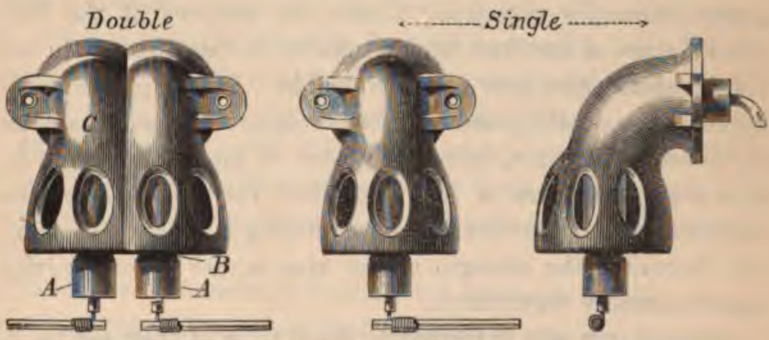


Fig. 6.

At the termination of all important wires, and, in many instances, at important signal boxes, "leading-in" cups are employed. They are formed (Fig. 6) of a porcelain tube, A, in

Mr. Langdon.

which the G.P. wire is threaded, the tube being contracted at B so as to keep the wire central and free from the edges of the tube. This tube is protected by an iron hood, C, perforated, so as to admit of the rain cleansing the porcelain tube.

Where round creosoted poles are employed for leading-in wires, it is necessary to carry the G.P. wires in boxing fixed between the arms. If this boxing is strongly made it will admit of the leading-in cups being fixed to either side of it, and will thus form a very complete and durable termination.

Wire.

Considerable progress has of late years been made in the employment of copper wire. The first copper wire erected for telegraph purposes was, it is believed, that erected by Mr. A. Graves, of the North Eastern Railway, at York, about 1877. Mr. Graves on that occasion employed No. 14 gauge (·080 S.W.G.); and shortly afterwards, in 1880, copper wire of the same gauge was erected on the Midland. The copper wire of various gauges in use on the Midland now extends to some 5,000 miles, of which 3,000 odd is maintained for the Post Office.

The objection to iron wire is the shortness of its life, and—in comparison with copper—its higher electrical resistance and greater inductive capacity. Under the auspices of the Post Office a class of iron wire largely superior to that formerly in use has for some years past been obtainable. This improvement—embracing conductivity and the general construction and character of the wire—does not, however, extend to prolongation of life. In a few years, more or less, dependent very much upon the condition of the atmosphere, the galvanising is gone, rust sets in, and thereafter the strength of the wire, as also its conductivity capacity, rapidly degenerates.

Covered iron wire is frequently found to be of great service in smoky localities. The best is that served with what is known as *West's compound.* The wire is lapped with cotton, and then passed through a special liquid composition, so that the cotton covering may become saturated by it. It differs from all other covering processes in that the composition hardens when exposed

to the air, is unaffected by changes of temperature, and when hardened is impervious to wet. So long as the covering remains sound the wire beneath it retains its original condition, and when the covering is removed appears as fresh as when new. Mr. Langdon.

A sample of some of this wire which has been in use on the Midland for some years will be found on the table.

The conductivity resistance of a 12½ gauge (·097) copper wire is 5·934 ω per mile; that of No. 8 (·160) gauge galvanised iron wire is 12 ω per mile. The breaking strain of the 12½ copper is 490 lbs.; that of No. 8 galvanised iron, 1,100 lbs.

The cost of a mile of 12½ copper is about £4 4s.; the cost of a mile of No. 8 galvanised iron wire, £2 10s. The difference in price is considerable, but against this we are able to place many advantages: durability—which means less cost in renewal, a saving of certainly two out of three, which at 20s. a mile more than covers the additional cost; reduced strain, and less load on poles, which admits of their reception of a greater number of wires; and last, though not the least important, less liability to fracture.

It is probable that 12½ copper, or possibly a slightly larger gauge, will entirely supersede galvanised iron wire; for, although when new the galvanised iron wire has the advantage in tensile power, it retains that power a portion of its life only, and during the latter part of its existence its tensile strength is even less than that of the 12½ copper. Its electrical resistance is, even when new, more than twice that of the copper wire.

It is desirable in using 12½ gauge copper wire, where possible, to slightly reduce the length of span—to limit it to 70 yards on the curve and 75 on the straight—say 24 poles to the mile, instead of 22.

In all newly constructed lines for the Midland Company's own purposes, copper wire is now used; and in the renewal of existing wires, iron is, as a rule, being replaced by copper.

In the erection of either copper or iron wire, the degree of tension to which the wire is pulled up is a factor which plays an important part in its durability. Wiremen, until they are taught otherwise, have a profound contempt for the effect of temperature

Mr. Langdon. upon the material they are using. On a hot summer day, or a bleak winter morning, they will pull the wire up to the same degree of tension. The consequence is that the wire erected under its maximum expansion in the hot noontide, is either broken or stretched under the influence of a lower temperature. The dip, or the stress, imparted to a wire must always be governed by the temperature, for which purpose a thermometer, placed in a position analogous to the wire, must be used.

Where wires are run on the parallel system, if the top wire is erected to the required degree of tension, the eye of the wireman can, by it, readily regulate other wires in the same span. To impart to this wire the proper degree of tension, its stress must be determined by its "dip," or by what is known as an indicating tension-ratchel—the latter by preference.

Where wires are erected on the "revolving" system, it is impossible to avoid the use of the tension-ratchel if the wires are to enjoy a uniform degree of tension.

To Mr. W. H. Preece, C.B., F.R.S., we are indebted for much careful investigation of this important question, and by his courtesy I am enabled to add, in the Appendix to this paper, tabulated statements adopted by the Post Office showing the stress at which both copper and iron wires should be erected at various temperatures.

JOINTING.

The "Britannia" joint still holds its own, whether for iron or copper wire, but the ends, or "tails," which for years have been left bent up, are now cut clean off, it being evidently better for a joint to *draw* than to form an intermittent fault. The Post Office, with regard to copper wire of large gauge, before soldering

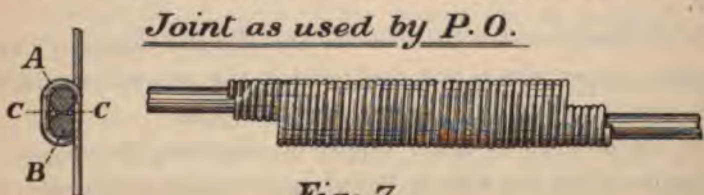


Fig: 7.

fill the interstices between the two wires, A, B (Fig. 7), and the

binding, by two pieces of smaller gauge wire, C. The object is to facilitate the soldering of the joint, and so prevent overheating the copper. The joint when completed is wiped clean, and allowed to cool. It should not be overheated, and it should not be chilled. Mr. Langdon.

Where joints are made in this manner, a jointing frame becomes necessary. This consists merely of a couple of clips, C, C (Fig. 8), in which the ends of the wire are held. It can with

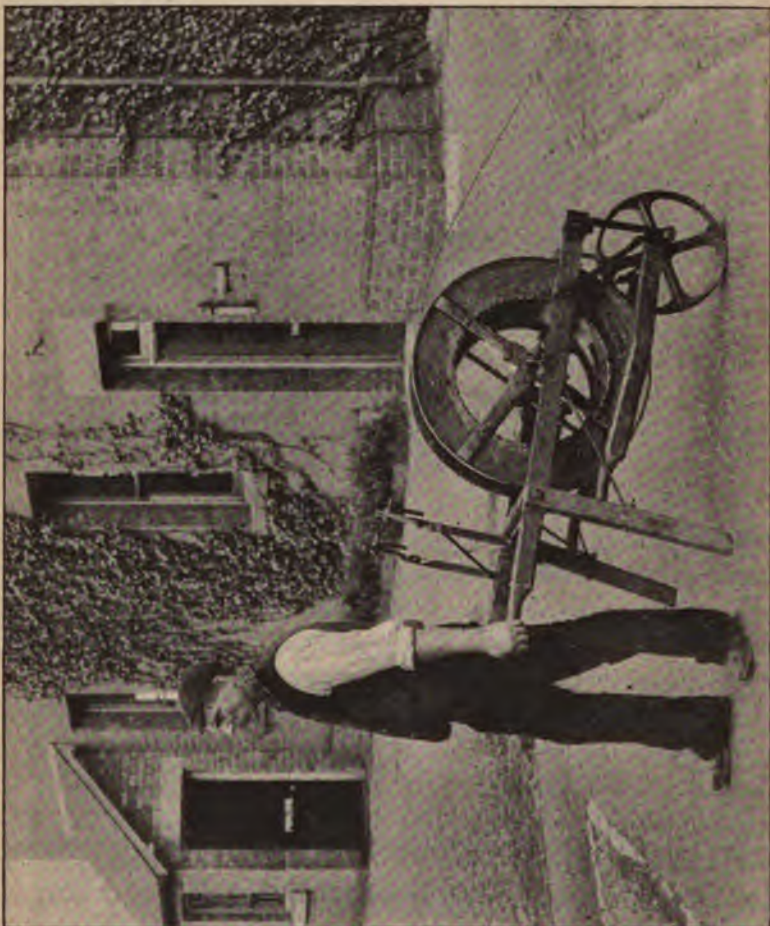
Fig: 8.

convenience be fixed by the legs, L, L, to the wiring barrow, or the legs may be thrust into the ground; and here, perhaps, although a minor matter, it may not be out of place to call attention to an improved "wiring barrow" which has recently been brought into use. These barrows are made with a frame similar to that of a garden barrow, but longer. The drum for the reception of the wire is made of sheet iron, and works vertically, instead of horizontally as hitherto. Ordinarily the barrow is wheeled along the sides of the line by one man, as on a public road; but where it cannot be wheeled, two portable arms, provided for the purpose, are placed in position, and the barrow is then carried in the usual manner by two men. The arrangement will be understood by reference to the photographs on the table.

Binding.

For many years the author has abandoned the use of No. 16 galvanised iron wire for binding, and has employed in its place

Mr. Langdon. a specially made No. 11 G.I. wire. It is necessary this class of binding wire should be more ductile than the ordinary conductivity No. 11 G.I. wire, and that it should be capable of being lapped around a No. 8 wire without scaling. If it scales it will

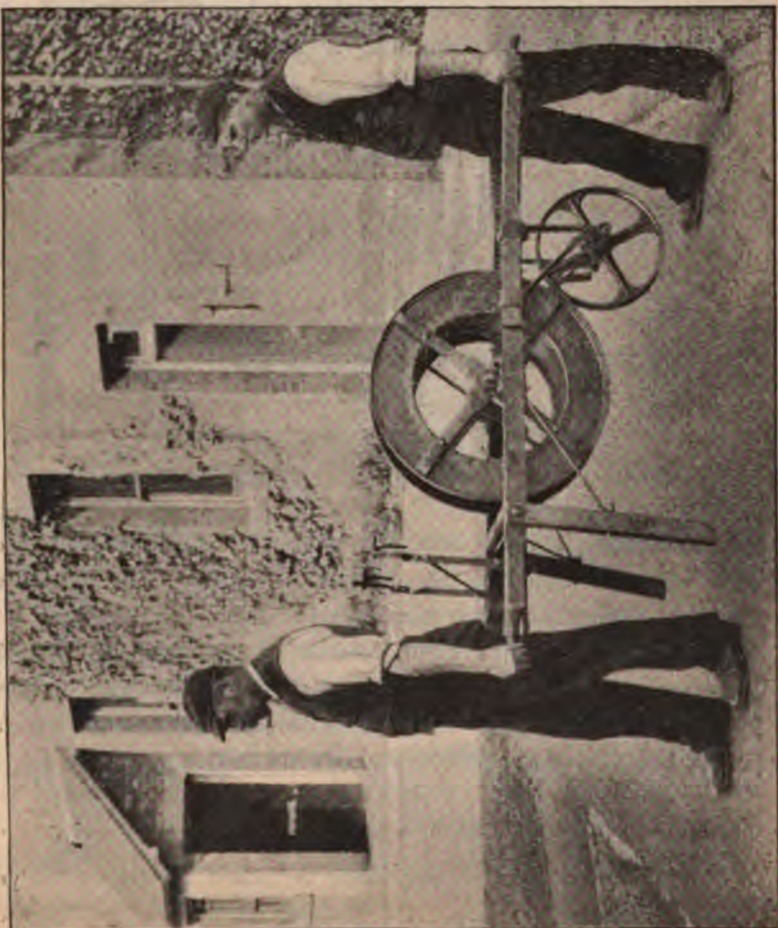


rust, and the oxide will be carried by the rain down the outside of the insulator cup, to which it will adhere to such an extent as may, in damp weather, materially affect the insulation of the wire.

In Fig. 9, C represents a cross section of an insulator, at the

point at which the binding wire is attached. The binder is merely lapped some five times around the line wire, as shown at B. It will be found that this form of binder will prevent a broken wire from running back quite as well as any form of binding with No. 16 gauge wire. Its advantages are: great durability, absence from stretch under influence of gales, less cost in construction and maintenance, and greater freedom from chafing—the line wire being much more firmly held. Mr. Langdon.

Fig: 9.



Mr. Langdon.

The practice thus pursued by the author has, in a modified form, been adopted by the Post Office with respect to copper wire. That portion of the line wire, A (Fig. 10), which rests against the insulator, B, as well as the portion which is to be lapped by the binder, is first overlaid by a copper tape, C—a piece of copper wire rolled out flat. The binder, D, is formed of a large gauge wire which has its two ends flattened so as to be readily laid around the taped portion of the line wire. Both the tape and the binder are first laid on by hand, the copper strip being exceedingly ductile, and finally tightened by the aid of a suitable pair of pliers; the complete binding being as shown by G (Fig. 10). Samples of these binders and tapes, as well as of the complete form of binding, are on the table.

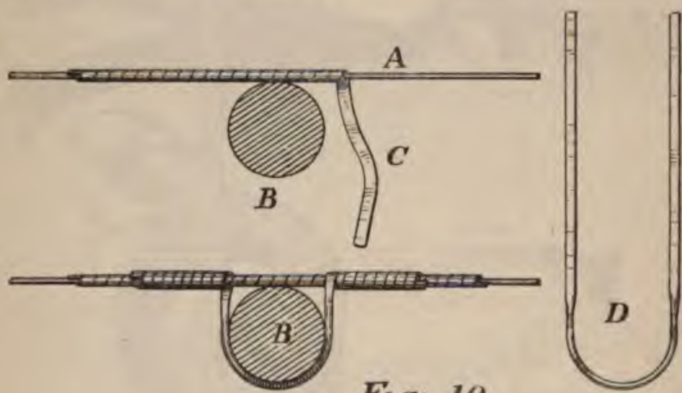


Fig: 10

The author is of opinion that wherever a sufficiently ductile wire can be obtained for the purpose, it is better to employ a binder of a gauge equal, or nearly so, to that of the line wire.

The Post Office, under the direction of the engineer-in-chief, have recently issued tables of sizes, weights of tapes and binders for the different gauges of copper wire, which, by Mr. Preece's permission, I have the privilege to append to this paper.

GUTTA-PERCHA AND COVERED-WIRE WORK.

It is believed there is very little to record in the matter of gutta-percha-covered wire. In making it a practice to use

ozokerite taped wire in all instances for underground work or for wooden casing, it is probable the author is merely following the practice of others. The taping adds very little to its cost and very largely to its life. The number of wires which are now required for signalling purposes,—the fact that, as a rule, the "leading-in" pole is placed in the rear of the signal box, while the instruments are invariably arranged over the signal lever frame in the front of the box,—leads to a large consumption of gutta-percha-covered wire, and renders it all the more necessary that every precaution should be adopted to preserve the life of the insulation. To this end all G.P. wires should be boxed in; and the boxing (which should be grooved from the solid), when carried underneath the floor of the signal box, should be inverted, so that any moisture from the washing of the floor of the signal box may not penetrate the boxing and impair the percha. Mr. Langdon.

The author has for some years employed wire covered with india-rubber, plaited cotton, and compound, for signal posts. It withstands heat much better than G.P.; the conducting wire is less liable to become decentralised; and he has good reason to believe that it will prove very durable.

Although instances have arisen where armoured cables composed of from three to ten conducting wires have been employed for telegraph and signal purposes, it cannot be said such are in general use. In station yards, where the wires are generally laid underground, and in other equally crowded places, armoured cables for odd lengths will probably be found not only useful, but, in order to avoid disturbing the body of through wires, a necessity. Such cables are extremely useful for crossing the line of railway for repeater, or similar purposes, where, unless the wires are carried underground, a large alteration is necessary in the poles in order to carry them overhead.

In laying down some underground work at Leicester and Nottingham, a simple form of cast-iron piping, which, having an india-rubber joint, is very quickly placed in position, has been used. It is inexpensive and readily handled. An illustration of the joint will be found in Fig. 11. A, B, are clamps which slide over the pipe, D, which is merely a straight tube.

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A, B, are recessed at A′, B′, so as to receive the small piece of tubing, C, together with an india-rubber washer, F, at either end. The pipes, D, are laid out so as to meet at C. A and B, as well

Iron piping for wires.

Fig. 11.

as C, are then slipped on, the tube C is brought into its proper position, and A and B are then closed up and tightened by the bolts, E. The india-rubber washers afford a firm grip, so that the pipes, D, are not readily drawn apart. The arrangement is better suited for level ground than for heavy slopes.

Wooden boxing for Wires

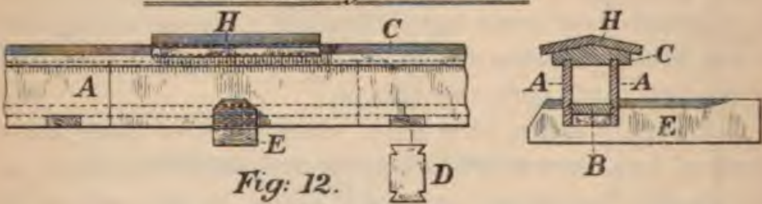

Fig: 12.

Fig. 12 represents a form of wooden boxing for tunnels and wall work. It is the production of my inspector carpenter, Hobday, and is set together, and maintained in position, without the aid of a nail or screw. It is formed of four pieces of wood. The side pieces, A, A, are grooved to accept the bottom board, B; the top, C, is grooved to accept the side pieces; the two sides are held together by tie-pieces, D, inserted at intervals of 3 feet. Instead of iron supports, wood blocks, cut from flawed or otherwise unsatisfactory oak arms, are shaped as shown by E to receive the boxing. These supports are fixed in the masonry by wood wedges or cement 6 feet apart. A piece of wire passed around the support and the boxing, holds the entire structure safely in position. No two pieces of wood from which the boxing is composed terminate at the same

point, with the exception of the lid. At the junction of these pieces a wooden capping, H, is employed to cover the seam. Mr. Langdon.

INSTRUMENTS.

In telegraph message instruments the vertical handle "single needle" remains that generally used in Great Britain. For some years it has been the practice on the Midland to employ, at the transmitting or terminal station of all busy single-needle circuits, a "Bright's Bell" in place of the single needle—an arrangement which will be found to aid dispatch and lighten the labour of the clerk. The Bright's Bell is also largely used by the Great Northern between telegraph offices. The Lancashire and Yorkshire and the Great Eastern employ it on single-needle circuits in a similar manner to the Midland.

Although the "sounder" is very generally employed for railway message work in Ireland, it cannot be said to have taken root on English railways. For direct and long circuits it is occasionally used, but, it is believed, not to any great extent.

For "quadruplex" working the demand does not appear to have been very urgent. It is employed by Mr. Hollins on the Great Eastern, between London and Harwich.

"Duplex" working is employed on the Great Eastern, Caledonian, London and North Western, and London and Brighton, and on the Midland. On the Midland a duplex circuit between Derby and London also provides for a phonopore communication.

The phonopore is employed to a very limited extent on the Midland, Great Western, Great Eastern, Brighton, and North British lines.

Telephones, as was to be anticipated, are now very generally employed for *vivâ voce* communications between signal boxes, and at busy centres between the administrative offices. That their employment largely aids the disposal of traffic there can be no question. At many points, and under exceptional conditions of weather, they are invaluable.

On the Continent, as well as at home, serious rumours have, from time to time, arisen with respect to the dissemination of

Mr. Langdon.

disease by means of these instruments. It has been contended that a person suffering from throat or other internal affection, on speaking into a transmitter, may leave in the interstices of the instrument germs of the disease, which may be inhaled by others using the same instrument.

Telephone. Wood Diaphragm.

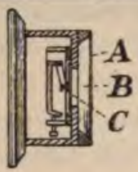

Fig: 13.

Fig. 13 represents a transmitter which has been designed with a view to obviate any such evil effect. The ordinary mouthpiece is removed, and in its place the entire face of the instrument is covered by a diaphragm, A, made of wood or metal—the former by preference—which encloses an air space, B, between it and the ordinary, or electrical, diaphragm, C. On speaking in the neighbourhood of the outer diaphragm its vibrations are transmitted by the pressure of the enclosed air to the electrical diaphragm. Speech is marvellously clear, and only when used for long-distance telephony—as between London and Glasgow—is any diminution in the sound noticed, and then only in a very slight degree.

Block Signalling Instruments.

The practice of arranging the block signalling instruments apart from the signal frame has with most companies been abandoned. As a rule, all block apparatus is now fixed on a shelf immediately over the signal frame, so that they may be readily manipulated by the signalman, and their indications remain present to his view.

With the exception of the introduction of Tyer's tablet block, and Messrs. Webb and Thompson's electric staff for working single lines, there is little of novelty in block instruments to record.

Interlocking the electric with the mechanical signals has made but little progress. The mileage of railway lines in Great

Britain* worked under the absolute block is 26,398. A very small fraction of this has the electric signals interlocked with the mechanical signals. Mr. Langdon

It appears almost marvellous that the enormous traffic which now passes over our railways should be conducted with so few casualties under an arrangement which entails a perfectly independent action for both the electric and the mechanical signals. The former are provided for the regulation of the traffic between signal post and signal post; but where they are not interlocked with the mechanical signals, which are those which actually guide the engine-driver, they merely indicate to the signalman how he is to work his signals; they in no way control them! That so few casualties arise testifies in the highest degree to the care and watchfulness exercised by the signalmen to whom falls the duty of working the traffic under such conditions. The subject is one which may well lay claim to further consideration at the hands of some member of this Institution. In the meanwhile, it may be desirable to point out that the interlocking which has, so far, been employed, is still wanting in finality. As now used it is the first vehicle which releases the lock. Needless to say, it should be the last.

Electric "signal repeaters" and "light indicators" have become indispensable adjuncts. On the Midland there are no

* EXTRACT FROM BOARD OF TRADE RETURNS, YEAR ENDING 31ST DEC., 1894.

—	Total Length of Railway open for Passenger Traffic.		Distance Worked by Absolute Block.			
				Distance of Single Line.		
	Double.	Single.	Double Line.	Worked by Train Staff System in addition.	Worked without the Train Staff System.	Worked on Electrical Train Staff or Tablet System.
	M. CH.	M. CH.	M. CH.	M. CH.	M. CH.	M. CH.
England and Wales ...	9,281·49	4,376·55	9,266·69	2,263·18	42·39	1,680·66
Scotland	1,289·09	1,761·00	1,287·19	222·04	119·43	961·61
Total for Great Britain	10,570·58	6,137·55	10,554·08	2,485·22	162·02	2,642·47
Ireland	613·00	2,414·52	613·00	451·09	0·70	1,555·51
Total	11,183·58	8,552·27	11,167·08	2,936·31	162·72	4,198·18

Mr. Langdon.

less than 3,000 of the former and some 800 of the latter in use, and with many other companies the number is no doubt as large.

Another useful adjunct is that termed the "repeater disc," employed to indicate the movement of the lever of "slotted" signals. It differs from the signal repeater in that the indicator, when passing from the ON to the OFF indication, directs the signalman's attention to the alteration by ringing a bell. (Fig. 14.)

Repeater Disc

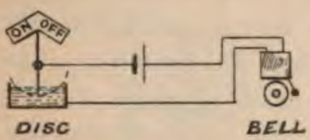

Fig: 14

"Light indicators" should be so constructed that they may indicate any failure in the light by a continuous ringing of the bell. This entails the maintenance of the *Light In* signal by permanent current. Two No. 1 *Leclanché* cells work the instrument perfectly well. Fig. 15 is a diagram of the connections.

Light Indicator.

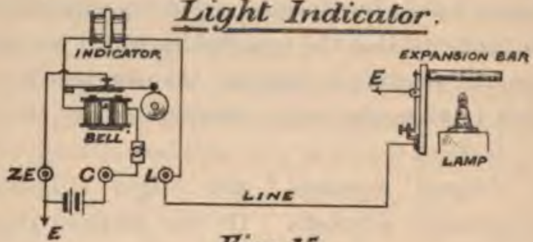

Fig: 15

Fig. 16 is a diagram of the signal repeater arrangement, the batteries being placed at the signal post. The ON contact, B, is

Repeater

Fig: 16.

fixed, and the contact which the tongue-piece, A, makes with it is only sufficient to admit of a movement of 2 degrees. The *contact C is* adjustable. Samples are on the table.

Batteries.

Mr. Langdon

To the Bichromate and Leclanché battery the author ascribes the palm of merit for a good and useful battery for railway purposes. For hard and constant work the former is unsurpassed. For occasional purposes, and for constant action, under certain limitations, the Leclanché commands attention. The old form of Daniell (sulphate of copper) battery, it is assumed, no longer finds a profitable field in railway telegraph work.

The Leclanché-Barbier cell is the latest development of the liquid Leclanché type of battery. It differs from the preceding types in the form of the positive element, together with other mechanical details. The positive element consists of a hollow cylindrical agglomerate of carbon and peroxide of manganese, around the upper part of which is cast a metal ring, caused to fit the neck of the jar, between which and the metal ring an india-rubber washer is inserted. The centre of the cylinder is covered by a wooden block, which serves to support the zinc and to close the jar. There is thus little possibility of evaporation; the cell is practically hermetically closed, and is in every way satisfactory.

The most recent innovation in batteries is the so-called "dry "cell," but of them the author cannot profess to any lengthened experience. In their early days they were frequently disappointing and unreliable. Much of that has now been remedied; yet, it is doubtful if their employment on railways would be economical, for it would still be necessary to retain linemen and battery men, or assistant linemen, to attend to failures of instruments, &c., when such arose. General freedom from such failures would in no way modify this demand for the presence of the linemen. Failure at some time would be certain to arise. Whenever it did, the lineman must be there promptly to attend to it, or the traffic would necessarily suffer.

I feel that, in submitting to your consideration so lengthy a paper, I have largely encroached upon your time and patience. It has, however, been impossible for me to deal with the subject in less space, and equally impossible to divide it into two parts. I believe that you will, under these circumstances, generously accord me your kind indulgence. As it is, I fear I may still have

r.
ngdon.

omitted some points of interest; and that, possibly, a want of knowledge of that which has been, or is being, done by others may even now render my treatment of the subject incomplete. Where such is the case, I must trust to my *confrères* to supply any such deficiency, in the discussion which the paper may elicit.

Mr. Langdo

APPENDIX.

Post Office Tables for Stresses to be observed in erecting Copper Wires at various Temperatures.

Temperature in Degrees Fahr.	Stresses in Lbs. for various Spans in Yards.																				Temperature in Degrees Fahr.
	150 Lbs. per Mile. (97 Mils. Diameter, No. 12½ S.W.G.)					200 Lbs. per Mile. (112 Mils. Diameter, No. 11½ S.W.G.)					400 Lbs. per Mile. (158 Mils. Diameter, No. 8 S.W.G.)					600 Lbs. per Mile. (193 Mils. Diameter, No. 6 S.W.G.)					
	50 yds.	60 yds.	70 yds.	80 yds.	90 yds.	50 yds.	60 yds.	70 yds.	80 yds.	90 yds.	50 yds.	60 yds.	70 yds.	80 yds.	90 yds.	50 yds.	60 yds.	70 yds.	80 yds.	90 yds.	
	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	
22	120	120	120	120	120	160	160	160	160	160	320	320	320	320	320	480	480	480	480	480	22
25	96	102	106	109	111	129	136	142	145	148	258	272	284	290	296	386	409	425	436	444	25
30	76	84	91	96	99	102	113	121	128	133	204	226	242	256	266	306	338	364	383	399	30
35	65	74	81	86	91	87	98	108	115	122	174	196	216	230	244	262	295	323	346	365	35
40	58	66	73	79	84	77	88	96	106	113	154	176	192	212	226	232	265	294	318	338	40
45	52	61	68	74	79	70	81	90	98	105	140	162	180	196	210	211	243	271	296	317	45
50	48	56	63	69	75	65	74	84	92	100	130	148	168	184	200	194	223	253	277	299	50
55	45	53	59	65	71	60	70	79	87	94	120	140	158	174	188	182	211	238	262	284	55
60	42	50	56	62	67	57	66	75	83	90	114	132	150	166	180	171	200	226	250	270	60
65	40	47	53	59	65	54	63	71	79	86	108	126	142	158	172	162	189	214	238	260	65
70	38	45	51	57	62	51	60	68	76	83	102	120	136	152	166	153	181	205	229	249	70
75	37	43	49	55	60	49	58	66	73	80	98	116	132	146	160	147	173	197	220	240	75
80	35	41	47	53	58	47	55	63	71	77	94	110	126	142	154	141	166	190	212	232	80
85	34	40	46	51	56	45	53	61	68	75	90	106	122	136	150	136	160	183	205	225	85
90	33	39	44	49	54	44	52	59	66	73	88	104	118	132	146	131	155	177	199	218	90
95	32	37	43	48	53	42	50	57	64	71	84	100	114	128	142	127	150	172	191	212	95
100	31	36	42	47	52	41	48	56	62	69	82	96	112	124	138	123	146	167	188	207	100
Poles per mile	35	29	25	22	19½	35	29	25	22	19½	35	29	25	22	19½	35	29	25	22	19½	Poles per mile

Mr. Langdon.

Post Office Tables for Stresses to be observed in erecting Iron Wires at various Temperatures.

Temperature in Degrees Fahr.	Stresses in Lbs. for various Spans in Yards.									
	200 Lbs. per Mile. (121 Mils. Diameter, No. 10½ S.W.G.)					400 Lbs. per Mile. (171 Mils. Diameter, No. 7½ S.W.G.)				
	50 yds.	60 yds.	70 yds.	80 yds.	90 yds.	50 yds.	60 yds.	70 yds.	80 yds.	90 yds.
	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
22	135	135	135	135	135	270	270	270	270	270
25	120	124	127	128	130	239	247	253	256	259
30	103	110	115	119	122	205	219	230	238	243
35	91	100	107	112	115	182	199	213	223	230
40	83	92	99	105	110	165	184	198	210	219
45	77	86	94	99	105	153	172	187	199	210
50	72	81	89	95	101	143	161	177	190	201
55	67	77	85	91	97	134	153	169	182	194
60	64	73	81	88	94	127	146	162	175	187
65	62	70	78	85	91	121	139	155	169	181
70	58	67	75	82	88	116	134	149	163	175
75	56	64	72	79	85	111	129	144	158	170
80	54	62	70	77	83	107	124	140	153	165
85	51	60	68	75	81	103	120	135	149	161
90	50	58	66	73	79	100	117	132	145	157
95	48	56	64	71	77	97	113	128	142	154
100	47	55	63	69	75	94	110	125	138	150
Poles per mile...	35	29	25	22	19½	35	29	25	22	19½

Factor of safety of 4 at 22° Fahr. for all wires.

The stress varies with both the gauge and the material.

The stress for 100 lbs. (No. 14) copper wire is half that for 200 lbs., and the stress for 800 lbs. (No. 4½) copper wire is double that for 400 lbs.

Mr. Langdon.

Post Office Tables for Copper Tape Binders.

Weight of Wire per Mile.			Length of Binder.	Copper Tape.	
Line.	Approximate Gauge.	Binder.		Length.	Width.
Lbs.		Lbs.	Inches.	Inches.	Inch.
800	$4\frac{1}{2}$	400	19	24	$\frac{1}{4}$
600	6	400	19	24	$\frac{1}{4}$
400	8	200	19	23	$\frac{3}{16}$
200	$11\frac{1}{2}$	150	17	22	$\frac{5}{32}$
150	$12\frac{1}{2}$	150	17	22	$\frac{5}{32}$
100	14	100	17	22	$\frac{5}{32}$

Mr. W. Langdon: I should like to read one or two letters which I have received on the subject. Mr. Graves, of the North Eastern Railway, writes:—

Telegraph Superintendent's Office, York,
April 28th, 1896.

Dear Sir,—Since writing to you I have received the proof of your paper. On page 394 I read that "the first copper wire erected for telegraph purposes was, it "is believed, that erected by Mr. A. Graves, of the North Eastern Railway, at York, "about 1877." This is not correct. The first copper wire I erected was in July, 1871, and was put up between a point in the Newcastle Station Yard and a point in the Gateshead Yard, on the south side of the Tyne. Copper wire was used on this railway in a number of places, chiefly in the neighbourhood of Newcastle, before it was erected in York in 1877.

Yours truly,
A. GRAVES.

W. Langdon, Esq.,
Telegraph Department,
Midland Railway, Derby.

Mr. Preece has also sent me a note, in which he says: "I "think you are wrong about Mr. A. Graves being the first to put "up copper wire. All the first lines in England (Paddington and "Slough) and in America were of copper; and the Post Office in "Birmingham put up some copper, *to resist corrosion*, about 1874. "But the great start in copper was made by me when I induced "the powers that be to run up a copper wire from London to "Newcastle, which proved that we not only reduced resistance, "but reduced static capacity and eliminated electro-magnetic

Mr. Langdon. "inertia, and thus increased the speed of working. We also "introduced copper for telephone circuits for the same reason.

"I read a paper about copper before the B.A. at Aberdeen."

The information in my paper was obtained some time since, and of course I am very glad to place these corrections before the meeting.

Mr. Wyles. Mr. F. WYLES: I do not know that I am prepared to discuss Mr. Langdon's paper with regard to the telegraphic arrangements, because we generally accept what is done on the Midland as the best thing to do. I think that is well known amongst all railway telegraph engineers. But the question of interlocking has not been dealt with very much, and Mr. Langdon almost invites another paper to be read at a later time.

I might say that the congested traffic out of London, at any rate on the southern side, is all controlled electrically. On the South Western, from Waterloo, we are working electric lock and block as far as Esher and Twickenham; everything is completely interlocked, and we are extending the system very largely. Cannon Street, on the South Eastern, London Bridge, Charing Cross, and other boxes are electrically interlocked.

There is a lot of interlocking done on the Brighton Railway, and a very great deal also on the Great Eastern.

The London, Chatham, and Dover, and District Railways are, moreover, almost completely fitted.

On our line especially, we are largely called upon to assist the mechanical department by doing much of their work electrically which cannot be done mechanically. Electrical fouling bars are becoming very largely used, and they are put down by the telegraph department; but they are always asked for by the mechanical department to assist them in their work, and to help the traffic, and to secure greater safety. We have a good many cases where signals are thrown to "Danger" electrically.

Then, with regard to single lines, we have an arrangement on the South Western Railway that was devised by Mr. W. R. Sykes, in conjunction with myself, by which the starting signals are controlled, and you cannot lower a starting signal unless the tablet is previously drawn.

This locking applies generally to all single lines worked by tablet on the South Western system. Mr. Wyles.

Mr. C. GOLDSTONE: I am somewhat surprised to find that so little is being done generally throughout the kingdom in connection with interlocking. On the South Western we have at the present moment in use something like 150 miles of electrical interlocking. We have large orders in hand, and I apprehend that by the end of this year quite a third of the line will be interlocked, and certainly all the busy portions of it. As Mr. Wyles has remarked, we are also called upon to actuate signals—the train having to throw up signals electrically as it passes them; we are doing a great deal in train-describing; and, in fact, at no period of my experience of block signal working have we been making greater progress than we are at the present moment, and principally in connection with interlocking. Mr. Goldstone.

Mr. C. E. SPAGNOLETTI: This paper wants a great deal of digestion to discuss it properly; but we must compliment Mr. Langdon upon the paper, which gives so much information, and I have no doubt to many of the younger members of our Institution there will be a very great deal of information obtained from it that will be entirely new to them. There are one or two points in the paper which I think want a little discussion. One thing which I rather take exception to is the system of the poles in Fig. 1 and Fig. 2. The H-pole system, as we call it, has been now used for a very considerable time. I think Mr. Langdon's system of putting up the H poles may be improved. You will notice at the bottom of Fig. 1 that the side piece of the poles here is bolted through. If one of those poles were to sink—and they weigh over a ton in many cases—it would cause a hinge action on the other. The iron cross-piece in the centre would to a certain extent stop that, and the cross-arms being slotted into the poles would also assist in preventing the sinking; but there would be a very heavy strain upon the arms and upper portion of the pole. When putting up poles of that description, instead of putting the bottom cross-pieces on the side of the pole, it is better to put one flat at the bottom, so as to give it a bottom Mr. Spagnoletti.

Mr. Spagnoletti. bearing; and by that means we get a very much more substantial foundation for the pole. Then, instead of putting a cross iron bar in the way shown in Fig. 1, we generally put two cross-pieces of wood bolted through the pole at each end of the cross-pieces, which are slotted into the poles, which makes a stronger structure. Now in this pole here (Fig. 2) there are no cross-pieces either above or below the ground line. If that pole were to sink, the whole of the strain would be put upon the cross-arms at the top; and I think, if Mr. Langdon examines the matter, he will find an alteration might be made for the better. Then, with regard to the staying of the poles, that is a most important matter, and one that I have given much thought to, because we had such a very great difficulty in staying the poles properly. And I introduced the screw staying-rods to get over the difficulties; but I found it necessary to go further, and use cast-iron stay-plates instead of wooden stay-blocks—as, when these became rotten, the heads of the bolts pulled through the blocks, although creosoted. In cast-iron stay-plates the rod goes through a round hole in the centre of the plate, which has two flanges, one on each side, to keep it from turning round, and these make a most substantial and lasting support to the pole; and, being made of cast iron, they last very well in the ground. I have not done very much with the iron arms, but we do not always earth-wire the arms. Mr. Langdon also speaks of the snow falling on the wires. The stays are of paramount importance in snowstorms, because the damage snowstorms may do is terrifying. We have had as many as 30 or 40 miles down at a stretch, where the wires have broken and let the poles down, the wires being twisted and in a shocking state. The great difficulty with the snow is this—that the snow will attach itself to the wires and gradually grow into large cables, until the whole of perhaps 20 wires will become one mass of ice; and then the wind, swaying this large substance, snaps the wires on one side of the pole, and it is pulled down by the strain and weight of the wires on the other side, and the poles run down for some considerable distance—many miles. Such disasters have been got over now to a great extent by staying the poles, say every fifth pole, with the wires as well as laterally. If you stay one

pole first on the right side, and then the next fifth pole on the left side, longitudinally, you have always got the counter strain should the wires break, and that prevents the running down of the poles for more than five poles; and that is of very great assistance in repairing the line after a snowstorm and rectifying any damage caused by the snow. With regard to insulation, Mr. Langdon states that he has adopted the system on the Midland of having one gauge of iron wire—No. 8—and also one class of insulator. That is a very good thing to do, and I think most lines now generally use one class of insulator; but I do not see why, in the open country, iron wire should not be used. Mr. Langdon, in speaking of the copper wire, seems to have a great preference for it. There is no doubt that for lightness and conductivity and long circuits it is a very excellent wire to use; but on small country branch lines, where you have a pure atmosphere, an iron wire is quite equal to our wants—we do not know the end of it yet. Some, I know, has been up for 35 years, and is still very good wire; and, as Mr. Langdon shows by the prices he gives, it is very much cheaper, and would save the expense of extra poles to reduce the spans. Copper wire, too, is very difficult to handle. You want to have very careful linemen to erect it. I think, if you were to see the list of instructions issued by the manufacturers of copper wire as to how it should be put up, and the care that should be taken not to damage the skin or overheat the copper, or scratch it in any way, it would rather frighten you from using it. With regard to the terminal insulator, that is very good; but it is liable to pull over, because all the strain is at the top and the fixture is at the bottom. Now with the shackle you have the strap at the top and the strap at the bottom, and you pull straight upon the bolt between the two; although I am bound to admit the insulation of the shackle is not so good as the insulator, which also gives a very excellent system where you have to join thin wires to thick, as Mr. Langdon has shown in Fig. 5. But the shackle possesses the same advantage as the iron, running well up into the insulator past the corrugations, in preventing the wire from falling. I do not think there is any advantage in the terminal insulator over the shackle in this

Mr. Spagnoletti.

Mr. Spagnoletti.

respect; for in case the earthenware, or crock, as some people call it, gets broken, the result is the same. These leading-in cups (Fig. 6) are very useful things, but I do not think they can be considered a new introduction. I believe Mr. Latimer Clark introduced them many years ago. I recollect them, certainly, for very many years myself. Then, with regard to the shortness of the life of the iron wire which Mr. Langdon speaks of, that depends entirely upon the position in which the wire is fixed. In South Wales, when you get amongst the copper smoke, the life of a No. 8 wire is not more than from 3 to 3½ years; at Birmingham, where the air is bad, but not so bad as in South Wales, it will last for 4 or 5 years; near London it will last for 6 or 7 years. Therefore it depends entirely upon the position in which the wire is placed. The same with copper wire. No one would erect copper wire where sulphurous acids abound and charge the air. The covered wires which Mr. Langdon refers to are very good and lasting in bad atmospheres. He specially mentions West's compound, which is a very good preservative and lasts well; but it is liable to fray, I have found. But I used a good covering by boiling tar—boiling it for some time—putting a little lime in it, and taking the water out. If you warm your wire, and then put it into the boiling tar, and then sand it with fine sand—with the sand of the ironstone—it is coated with a covering which is quite equal to—in fact, better than—any other compound I have seen. There was some of this covered wire put up between Wolverhampton and Worcester, and I think that wire is now as bright underneath the covering as it was on the day it was put up; and it has been erected for about 35 years, and it is still in excellent condition. But the worst of these covered wires, as with copper wire, is that they are so liable to get damaged when you put them up: when you draw and tighten them up, the grip of the vice upon the covering very often damages it and tears the coating, and it has to be painted or tarred over in order to cover those places up; otherwise, if they were left exposed, the strongest link of the chain would be the weakest. With regard to the interlocking system, Mr. Goldstone and Mr. Wyles

have spoken of that as the system which is the coming system, and in this I quite agree. For the last 12 years the Metropolitan Railway have adopted it, and now have it throughout the whole of their system; and they also have a system for shunting, and for protecting trains when they are on the wrong line, and while crossing from one line to the other. The system is arranged that if a train should come on the "up" line and has to cross to the "down" line, while it is on the up line the up line is blocked, while crossing to the down line both lines are blocked, and when it gets on the down line the down line is blocked and the up line is freed; trains may be crossed as frequently as possible with safety. When both lines are occupied both lines are blocked; but as soon as one is clear of the train the electrical action of the treadles used for the purpose releases the instrument and the signals can be worked for a following train to come on, and you may pass trains as fast as you like without any danger at all. It is used on several lines now. I should like to say one word about the iron tubing (Fig. 11). I have used it, but found very often that the workmen with their pickaxes would break them, and damage the wires they contain very much; and it was always found better to put a bit of good thick oak or elm shuting down: then, when they chanced to put their pick into that, it was held, and there would be an indication that they were going into something before they did any damage. Mr. Spagnoletti.

Professor PERRY: At the outside of the pipe?

Mr. SPAGNOLETTI: No; no pipe at all—wooden shuting—wood instead of iron. Many railways are now using the phonopore telephone, which gives us the opportunity of speaking upon telegraph wires while they are at work. We can talk with the greatest ease, and run five, six, or seven stations upon the telegraph wire, or attach to it telephone circuits, and although the telegraph may be working on that wire we could hold the conversation without any difficulty whatever simultaneously. These telephones can be attached at different places on a long telegraph circuit, and thus provide short circuits, or attached to the connection of the telegraph wires in t

r. pagnoletti. telegraph office and carried into the general offices, and so make circuits anywhere you like, utilising at the same moment the telegraph and telephone together, saving the erection and maintenance of additional wires; and if two wires are used to form the circuits, if either breaks the telephone communication is still maintained. Whatever prejudice may exist against the phonopore telegraph, the telephone is without doubt a very valuable instrument, particularly to railway companies.

With regard to signal arm repeaters, lamp indicators, and signal slot indicators, some years ago, on the Great Western Railway, I introduced a system by which with two wires and one instrument we could indicate the position of nine or ten or more signal arms, and the condition of nine or ten or more signal lamps (whether burning well or not), instead of using 18 or 20 wires and eight or ten instruments, as the old system required; and this to railway companies is of considerable value, as now so very many of the signals are required to be repeated by the Board of Trade. Mr. Goodenough, the present engineer of the Great Western Railway, will no doubt explain the system introduced, with the additions and improvements that he has carried out since the introduction of this system.

Dry-cell batteries have been improved very much lately, and some of them do their work remarkably well; they want testing from time to time, and require watching, as all others do which are likely to fail sometimes if not attended to. Mr. Langdon asks us to supply any information we can on this subject, and I am pleased to comply with his request as far as I can do so.

r. Bright. Mr. Charles Bright: I should like to ask Mr. Langdon how it comes about that it is the general custom (as apparently it is) in railway telegraph systems to employ gutta-percha as the insulating medium for underground conductors in preference to india-rubber. I should also be glad to know why, in laying down G.P.-insulated lines, special precautions are taken to avoid moisture, which—provided the gutta-percha is in a good and homogeneous condition—is, I may say, usually considered by those concerned in this material the best possible accompaniment

I venture to think that the bulk of evidence is all in favour o

efficiently vulcanised india-rubber, of the proper mixture, as a means of insulation for perfectly dry soils, notwithstanding the greater trouble involved in joint-making. In such soils the essential oil of gutta-percha rapidly evaporates, the gutta-percha oxidises and cracks, finally dropping off the conductor as so much powder; thus, if an insulating material is considered to be necessary in a dry soil, its object has been entirely defeated. Ozokerite tape can but modify this tendency, however securely it may be applied; the gutta-percha is, in fact, thereby rendered more like india-rubber. Mr. Bright

Under alternating dry and wet conditions, my experience is that gutta-percha and india-rubber behave about equally badly. With india-rubber it is a case of more or less rapid decomposition, according as to whether the core has been inefficiently or properly vulcanised for the right length of time to the correct temperature. No matter what precautions may be taken, gutta-percha (if in the smallest degree exposed) is *bound* to perish under such circumstances. When the soil is perfectly dry it cracks in the manner, and for the reason, mentioned. On moisture, or water, finding its way to these cracks, the insulation resistance becomes mainly distinguished by its absence. With G.P. lines probably the most sure way to entirely overcome this trouble is to draw them through iron pipes kept constantly filled with water—a plan devised originally by Messrs. Clark, Forde, & Taylor. This is, at any rate, practicable for comparatively short lengths with no excessive gradients; though initially somewhat costly, and always troublesome for long lengths. It is, I believe, the plan which has been adopted, with complete success, by the Eastern Telegraph Company and its allies for their underground land lines in various parts of the world for many years past. Another common plan for all sorts of underground lines, applicable either to gutta-percha or india-rubber, is to hermetically seal the insulation by means of lead tubing. This is found to answer very well, provided the soil is not one which acts on the lead. Metallic taping doubly applied, with opposite lays and plenty of overlap, meets the case for a certain length of time.

By such protective methods, moreover (though materially

Mr. Bright. increasing the outlay), the encroach of any description of insect is also avoided in a manner altogether beyond the powers of ozokerite tape.

I presume that here, as elsewhere, initial cost is a secondary consideration as compared with securing the most reliable system, such as tends to reduce the chances of an interruption—maybe at a critical moment—to the finest point possible.

I have ventured to make these remarks as the result of experience with long lengths of both I.R. and G.P. lines, laid down at the same time in the same localities under the most trying conditions possible—*i.e.*, in a tropical climate, with dried-up soil and sand at one time of the year, flooded over at another by heavy rainfalls.

With Mr. Spagnoletti, I am unable to appreciate the ultimate advantage in the terminal insulator described in the paper over the ordinary Bright shackle.

Mr. Treuenfeld. R. VON FISCHER TREUENFELD: Telegraph engineers ought to be very thankful to Mr. Langdon for having brought before the Institution a subject which for many years has almost entirely been forgotten. I am pleased to see it mentioned that at least one branch in telegraphy—viz., interlocking—is still wanting in finality, and think you will agree with me that there are not only one, but a great many branches in telegraphy which are still wanting in finality. The general opinion prevailing in later years is that the sphere of action of telegraphy has run out, and that there is no further field for energy, intelligence, and development; but the young members of our electrical fraternity can be assured that that is not the case: there is plenty of room for intelligence and development. With regard to the paper, there are one or two points I should like to mention. The author refers to Mr. Alexander Siemens and iron poles. Mr. Alexander Siemens is not present, and perhaps I may be allowed to answer the question in his stead. Iron telegraph poles have been very largely and successfully employed, especially in the Colonies, in consequence of their durability, and their ease of transport for long distances. There is a strange fact which perhaps iron manufacturers can better answer than telegraph engineers, viz., that iron telegraph

poles of given dimensions will not stand the breaking strain nowadays that they did 25 years ago. This fact, and another more important one—viz., that iron poles have to carry more wires than they formerly did—has led to the necessity of finding out new constructions which give the pole greater stability. Mr. Siemens has succeeded in doing this by taking out a patent of a pole which is very simply arranged and perfectly balanced. Telegraph poles generally consist of a lower cast-iron tube and an upper wrought-iron tube. Formerly the upper wrought-iron tube was either cemented to the upper 6 or 9 inches of the lower tube, or screwed together by any of the patent joints, and it has lately happened that these poles break in the joints. Mr. Siemens has constructed a pole by which the upper wrought-iron tube is not exclusively fastened to the upper 6 or 9 inches of the lower tube, but goes right down to the ground, where it sets into a conical foundation, and this gives a very solid pole, much stronger than any of the older constructions. Perhaps I may be allowed to touch upon one point which is rather of importance. I wish to speak against the employment of copper wire, but in so doing I hope I shall not be misunderstood. I am fully aware of all the advantages of copper wire over iron wire. The favourable circumstance of electrical capacity, and the consequent increase in speed of working—which amounts to something like 25 per cent.—is quite enough to give preference to copper wire over iron wire. We have had laid before us a medal with a very bright surface; but that medal, like all others, has two sides, and the other side is perhaps not so bright, although it might not be so important: I refer to the very poor breaking strain which lines of copper wire have. The electrical resistance of copper as compared with iron wires varies very nearly inversely as its price per ton. Thus, if you wish to replace, without detriment to economy, a No. 7½ gauge iron wire of equal conductivity and equal price, we have to choose a No. 14 or No. 16 copper wire of 0·069 inches in diameter. The breaking strain of the No. 7½ iron wire is about 1,300 lbs., whereas that of No. 14 copper wire is only about 290 lbs. If we adopt the rule that the tension of the span of the wire should not exceed one-fourth of the actual

Mr Treuenfel

Mr. Preuenfeld. breaking strain of that wire, there would be left a reserve breaking strain of 867 lbs. for the iron wire, and only 193 lbs. for the copper wire, to oppose any extra tension or load, such as is caused by accumulation of snow, pressure of wind, &c. Supposing the cubic foot of ice and snow has a weight of 30 lbs., then an accumulation of 3 inches diameter suspended on either wire between two telegraph poles 260 feet distant would represent an extra load of about 13 cubic feet, with a weight of about 190 lbs. But this is not all. Supposing the wind had only a velocity of 40 feet per second, which is not a gale, this would cause an extra pressure of about 2 lbs. per square foot of projected cylindrical surface. This projected surface would be about 65 square feet, equal to an extra wind pressure of 130 lbs.; and adding this 130 lbs. to the load of snow and ice, we have 320 lbs. extra tension upon each wire, which would be double or treble that amount during a gale. As our copper wire—No. 14—only possesses 193 lbs. reserve breaking strain, it is quite evident that it must have been broken long before we arrive at the above condition of snow accumulation and wind pressure. The so-called equivalent iron wire—No. 7½—with its reserve breaking strain of 867 lbs., will still be intact after its modern competitor has long fallen a victim to the inclemency of nature, supposing that time and rust had not yet undermined the original strength of the iron wire.

Mr. Hollins. Mr. F. Hollins [*communicated*]: I am sure we are all obliged to Mr. Langdon for his very interesting paper. It is quite refreshing to have a paper dealing with telegraphy at all, and especially railway telegraphy.

I suppose it is only natural that Mr. Langdon should describe to us principally what he is doing upon his own line, leaving it to other railway telegraph engineers to add, as an addenda, what they are doing upon theirs. We are all aware that the telegraphs on the Midland are worthy of the company to which they belong, and are a credit to Mr. Langdon, who has entirely reconstructed the lines, and made them what they are.

I do not think there is anything in Mr. Langdon's method of construction, however, to call for, at any rate critical, remark. It is all very excellent and as it should be, and as we should expect from Mr. Langdon.

As regards West's covered wire, to which he refers, I may say Mr. Hollins. that it is the description of wire which is exclusively made use of on the Great Eastern Railway, in the London district (there is over 700 miles of it); and with proper care in putting up, and with occasional dressing, it will last 20 years. I scarcely ever have a fault due to defective covering, and plenty of the wire, I am told, has been up over 25 years.

As regards that portion of the paper under the heading of "Instruments," I should like to say that on the Great Eastern Railway "Bright's Bells" are made use of, not only at the terminal stations of single-needle circuits, but at all intermediate offices having a special telegraph staff. I entirely agree with Mr. Langdon that this considerably assists the despatch of work between telegraph offices, without interfering with the working to and from the booking offices on the same circuit.

As regards duplex working, I have adopted this on the Great Eastern Railway between London and Cambridge, and London and Norwich; and quadruplex between London and Harwich (Parkeston Quay); and they are found to be very little trouble: the staff soon get used to the working, and can adjust the apparatus promptly and with confidence.

The phonopore, on the Great Eastern Railway, was a failure, the receiving apparatus having to be replaced by a telephone. This is now in work between London and Ipswich; but a Morse key, induction coil, and one M.F. condenser with telephone, serve precisely the same purpose, and we have such an arrangement in work between several other points, and giving much satisfaction.

I may say that, in connection with the extensions of the Liverpool Street Station, we have provided a very complete system of pneumatic tubes for collecting and delivering the telegrams from the telegraph office to the several platforms, and general offices, and to the goods offices at Bishopsgate.

In some degree the arrangement is, I think, somewhat new, inasmuch as the engines are nearly half a mile away from the base of operations. It is a great success, and enables the message work to be dealt with very promptly, and with a minimum number of messengers. We also use it to pass correspondence between

Mr. Hollins. the general offices and the goods offices, &c. It is all completely under the control of the telegraph office; the carriers are passed backwards and forwards under block signal regulations, to prevent blocking of the tubes, and telephones are also provided to allow of prompt communication to the different stations, including the engineer.

We have also in the telegraph office a "Standard" telephone exchange switch in connection with every department, and which I need hardly add is greatly appreciated and much used.

It is rather disappointing that under the head of "Block "Signalling"—and electric interlocking comes under that head—we have nothing, in the paper before us, to indicate that railway companies have done anything. Surely under "Block Signalling" this should have more than a passing reference. Mr. Langdon tells us that the interlocking which has so far been employed is wanting in finality. True, and perhaps always will be; I do not agree that releasing with the last vehicle *will* give us finality; where the factor is safety we must not acknowledge the term.

The directors of the Great Eastern Railway have recently spent over £20,000 in providing a very complete system of electric interlocking, over all suburban lines, from Liverpool Street and Fenchurch Street to Ilford, on the Colchester line; and Tottenham, on the Cambridge line; and on the Woolwich and Enfield branches; and to Leyton, on the Loughton branch. Practically this means all lines and branches inside Ilford, Tottenham, Seven Sisters, and Leyton.

This has involved the complete fitting of some 80 signal boxes, and has involved some 150 to 200 miles of additional wire; over 10 miles of underground pipes to the rail contacts, and some 400 rail contacts. In addition to this, we have fixed about 500 electric locking instruments, controlling about 800 levers; and the rail contacts are supplemented or controlled in turn by about 90 electric bars, varying from 20 to 40 feet long. The system adopted is Sykes's, with the addition of his latest "Train on" gear. The instrument indicates when a train has been "accepted," when a train is *in* the "section," and whether the lever of the signal controlling the entrance to the section in advance is "locked" or "free."

The rail contact made use of is a self-adjusting friction clutch giving a rubbing spring contact, and the end or tail of the lever of which passes through, and is keyed into, a hole through the web of the rail. Where the rail contact is fixed, timbers are secured to form a bedding under the ends of the sleepers, and the contact is securely bolted to the timber and rests between the sleepers. Should there be any tendency, through the road giving, to make contact, each train as it passes readjusts the rail contact to the maximum distance the movement of the rails will allow the contacts to be apart. Mr. Hollin

With all these rail contacts in work (and some of them worked hundreds of times a day), there has not been a failure on the wrong side in 12 months.

At the entrance to sidings from the main line one of Sykes's bars is provided, and this precedes the rail contact, its duty being for the first wheel entering the siding to break the circuit down, to prevent the rail contact from unlocking, until the last wheel has passed into the sidings and over the bar. Many little additions and improvements have been added to the apparatus since it was fixed, giving increased security and reliability in working.

At one time I think it was contended that electric locking could not be used on very busy lines without delay to traffic; but I think the time-keeping of our local trains, all coming under this electric locking, completely disproves such a statement.

The number of failures are few; we are satisfied with its working, and I have no doubt it will eventually be still further extended.

I think Mr. Langdon's suggestion that some member of the Institution should deal in a special paper with electric locking as applied to railways, and to include anything new in block signalling, a good one; and, if no other railway telegraph engineer cares to do so, I will have pleasure, with the permission of the Council, in preparing such a paper.

I am much obliged for being permitted to add this account of some of the recent improvements in railway telegraphs on the Great Eastern Railway.

Mr. Hampson.

Mr. R. Stuart Hampson [*communicated*]: If the value of our Institution lies in its many-sidedness, then every member must feel grateful to Mr. Langdon for giving us, in his usual graphic way, an interesting survey of the service rendered to the working of railways by the electric telegraph.

It is sometimes objected that the papers read at these meetings deal almost exclusively with electric lighting subjects. Perhaps a little more variety would not be out of place; but it should be remembered that both these great branches of electrical science have much in common, and that we cannot discuss one without obtaining useful information regarding the other. Then the electric lighting is still in its infancy, and needs the fostering care of this Institution; whereas the electric telegraph is more advanced and matured, and consequently does not require to be discussed so frequently.

With regard to that part of Mr. Langdon's paper which deals with the question of copper wire, I think the late Mr. E. C. Warburton, of the Lancashire and Yorkshire Railway Company, who was a member of the Institute, was really the first to put up copper wire on a large scale for telegraphic purposes. I remember as one of Mr. Warburton's assistants doing some of the work in connection with an installation of copper wire about 1880. Perhaps the Lancashire and Yorkshire engineer will be able to give us some data respecting this particular wire, as I understand that it has recently been taken down and erected again on one of the branch lines. Since that time my experience of copper wire has been continuous. I am in favour of its exclusive use in smoky districts. It is to be preferred to covered wire of any description. Iron wire has been a very useful servant. In point of durability, in rural districts, I do not think there is much in it. I am just now taking down some iron wire which was erected 30 years ago in Lincolnshire. Copper will, however, win in the end, because of its better conductivity, and the fact that when you take it down you can sell the scrap at a very good price. In comparing the cost per mile, Mr Langdon might have given the labour item, which is largely in favour of copper.

I agree generally with Mr. Langdon's views on construction

work. He has given us a practical embodiment of those views in the splendid line he has recently erected on the Midland Railway for the Postmaster-General. It is a matter of common observation that it is one of the best lines ever built by a railway telegraph engineer. Mr. Hampson.

I could have wished that Mr. Langdon had told us something more about the apparatus used on railways. We ought to have been told that the vertical handle "single-needle" instrument is gradually being superseded by the more rapid "tapper key" instrument. At least this is so on the Manchester, Sheffield, and Lincolnshire Railway Company, where the "Bright's Bell," reduced to about half the size of that employed by Mr. Langdon, is also used.

I should have liked more information with regard to repeaters. I am not satisfied with his "light" indicator. If we examine the diagram of connections (Fig. 15), we shall find that in the event of a disconnection of the line wire the bell would ring, and the signalman would conclude that the light was "out." The indicator would, in fact, show "out," but the light might still be "in." Again, suppose the line gets to earth, the bell does not ring, even if the light is "out," and the indicator shows light "in," although the light may be "out."

We must have a third position to indicate that something is wrong with the circuit, in the event of the line wire breaking, before we can call Mr. Langdon's apparatus an accurate light-indicating arrangement.

I am afraid to trespass further. It is unfortunate that Mr. Langdon did not deal with the lock and block system. However, the omission may perhaps give me an opportunity of reading a paper on the subject before the Institution at some future time.

Mr. W. LEONARD [*communicated*]: Although Mr. Langdon is undoubtedly an authority on telegraph construction, and the importance cannot be over-estimated, his description on this point might equally apply to the Postal telegraphs. I see little to discuss, as the South Eastern Railway practice is almost uniform to that described. The question of iron and copper wire is debatable; but I am in favour of the latter, having erected it for the Mr. Leonard.

Mr. Leonard.

last 10 years in localities where iron wire has not a long life. I venture to think that his paper would have been of more interest to the majority of the members of this Institute if he had devoted less time to this, and more to the modern apparatus, which forms such an important addition to the railway telegraphs.

Electric interlocking is dismissed in a few words. Is it possible that it finds no place on the Midland Railway? On the Southern railways Sykes's system is being largely adopted, and proves of great advantage to the regular and safe working of the traffic, especially where it is crowded and complicated.

I can fully emphasise the views of the author as to the value of the telephone. The system is being extended to the whole of the signal boxes on the South Eastern Railway, and in the London district the metallic circuits are duplicated for local and through working between various points. A copper return wire is also provided for all circuits in the same locality.

Train describers (which are not mentioned by the author) are erected throughout the same area, their object being to indicate the name and route of the trains by sight instead of by sound. Where trains of a similar description travel on the same road, but diverge at a certain point, the indicator shows the route, and the describer the name. The tendency is to apply electricity to every purpose, and our work is ever expanding, and becoming more important as the traffic presses. We are indebted to Mr. Langdon for bringing the details up to date as far as he has done.

Mr. Fletcher.

Mr. G. E. Fletcher (L. & N. W. Ry.) [*communicated*]: I have read Mr. Langdon's paper with some pleasure, but, bearing in mind the title, I must confess that I am at a loss to discover any "recent" improvements, particularly as originating from a railway engineer, as it seems to me that the whole credit of improved devices is given to the Post Office; but, as I propose to take the points in the paper *seriatim*, it will be better to at once enter into them, and, if I bring my remarks into decent compass, I may be able to add something that may be of interest to the members.

I quite agree with Mr. Langdon that the increases such as

Mr. Fletcher.

have been mentioned necessitate our looking to the strength of our means of communication, namely, the lines; but, particularly regarding it from a point of view of construction, it must be evident that, if the construction is really first-class, the maintenence which follows will, as a consequence, be comparatively small.

Turning to the question of poles: The matter of creosoting poles is not of such recent introduction as to take up the time of the Institution by going into details, as it must be an accepted fact that up to the present time it is the best method of preserving timber for the particular purpose for which poles are required as applied to telegraphs—not only railway telegraphs, but to telegraphs in general.

Now I come to a point in the paper which I think calls for some consideration, *i.e.*, the question of H poles, and the arrangement adopted by most people, including railway companies. The existing method of arming either single, double, or H poles is bad. It should be asked why the pole is required to be of a certain dimension. To give a certain strength. But what is done? Holes are bored through, as per Fig. 1, and slots cut to receive the arms, giving result as shown in Fig. 2.

Fig. 1.

Fig. 2.

Fig. 3.

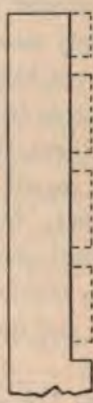

Fig. 4.

In Fig. 1 the holes are bored through, the effect of which is to produce a vault, equivalent to cutting a piece out of the centre equal to the diameter of the hole, and equal in length to the space occupied by the whole of the arms, as shown in Fig. 3.

Mr. Fletcher.

Then, turning our attention to Fig. 2, in conjunction with Fig. 4, the strength of the pole is further diminished, as must be evident to all. In Fig. 4 the dotted lines show the portions that are of little or no use except to stop the arms from twisting.

Going further into the question, the tying of the pole above ground as described in the paper is bad, as you practically have a pole as depicted in Fig. 5.

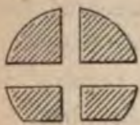

FIG. 5.

As I do not wish to be too lengthy, I ask, On the face of it, where does the additional strength of the H pole lie, when you have taken away that part of the timber in which the greatest strength is supposed to exist?

The North Western, I admit, have been in the habit of using this method; but the writer has for some time been employed on a plan by means of which the timber of the pole shall remain intact both for ties and arms. The ties have been tried, and found efficient, but the arms have not yet been finally arranged for.

I should like to question the arrangement in the paper for tying below ground, but I am afraid if I went into all these details I should occupy too much space. It will suffice for me to say, "Apply mechanics;" and it will be evident that the poles are certainly not locked by the tying. The only efficient method is the cross-tree arrangement: then, if the poles have a proper splay given to them, they will require little or no staying.

With regard to Fig. 2 in the paper I have nothing to say, except that, from an engineering point of view, no worse arrangement could be employed; in fact, it presents to my mind the "jerry builder," where first cost is everything, and maintenance nothing; and staying poles under such conditions only augments the evil.

Taking the question of arms, I am convinced that the iron arm is a most excellent arrangement, except for one thing, and that is the point which Mr. Langdon seems to say enhances its value. Mr. Langdon pays particular attention to the earth-wiring of pole-arms; I pay none, and here I wish to explain why. An iron pole-arm connected to earth has no resistance. A cracked

insulator in wet weather gives nearly full earth—but say 20 ohms; and, as he says, this is easily detected; but at what expense? The circuit is broken down; as it is very evident that, when the instruments and batteries are so proportioned that 17 milliamperes will work the circuit, with such an "earth" communication could not be continued. But take the case of a wooden arm with no earth wire except from the bolt: 4,000 ohms may represent the earth resistance. On the majority of circuits this will only have a slight effect—simply that the signals would of necessity be somewhat weaker; but still the communication would continue. The question resolves itself, then: if you can get sufficient strength, and maintain it, with wood, do not depart from it. Mr. Fletcher.

Looking at the question of staying, and again applying mechanics, you will find that nine-tenths of the telegraph poles to-day are stayed in the wrong place. But, more particularly directing your attention to the staying of terminal poles, take the length of span, wires coming on in different directions and numbers, and then consider the question in connection with the parallelogram of forces, and you will find that a considerable number of the stays used to-day can be dispensed with. This not only applies to railway telegraphs, but to telephones, &c.

Insulators.

I cannot quite reconcile the opening remarks of the paper under this heading with those in paragraph 4; they deprecate the use of minor insulators, whereas in the latter their use is recommended. In case of strain, that which meets the greater requirement also meets the smaller in exactly the same manner, as the better insulator, from an insulation point of view, meets both cases.

Proceeding to paragraph 5, I am prepared to agree with the author that there is an advantage in the bolt going so far up the porcelain, but on all other points I must disagree; especially I am afraid he gives his whole case away in the following remarks:—
". . . but make provision for the attachment of different gauges
"of wire, as, for instance, if it is desired to attach a No. 11 to a No.
"8. If the No. 8 is placed in the lower groove, and the No. 11 in

Mr. Fletcher.

"the upper groove, the strain on the bolt will be about equalised, "and the insulator will retain its vertical position." On the face of this it must be evident that, when such insulator is used purely and simply as a terminal insulator, it will not remain in the vertical or original position; and if the case be investigated further, it will be found that, with the foregoing result—which is, as I have said before, admitted by the author—the strain on the arm is such as will easily crack, if not break it, as will be evident from the following figure:—

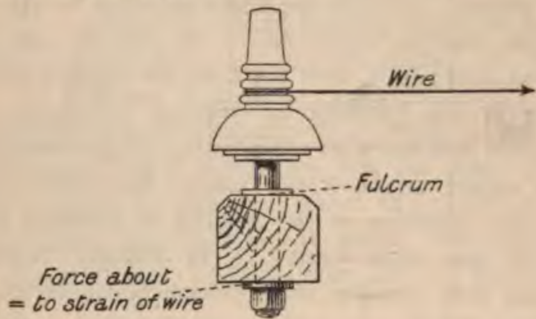

Fig. 6.

We have the simple question of the lever and fulcrum. Surely this is a weakness that, from an engineering point of view, cannot be overlooked. That the old form of Bright's and ring shackle do not give a satisfactory insulation resistance, it is unnecessary for me to say; but I submit that the strain on the arm is not such as will bring about the fracture of the arm at anything like so low a strain as in the previous case, as the strain is a tearing and not a twisting one. The following figure illustrates the condition of things—strain on arm, in direction of wire:—

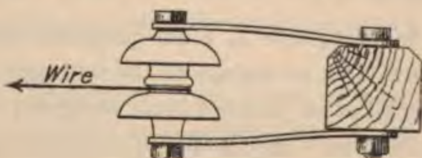

Fig. 7.

Before my entry into the electrical world, some 14 years ago, my present chief introduced a terminal insulator which I maintain

gives equal insulation results with the one described in the paper. But of this more anon; at present I will deal only with the mechanical question. Fig. 8 shows such insulators in position. Mr. Fletcher.

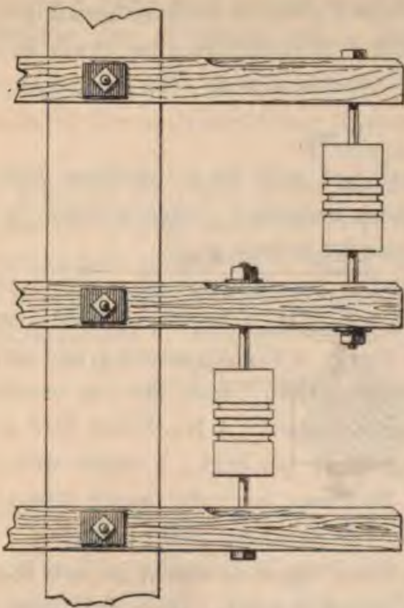

FIG. 8.

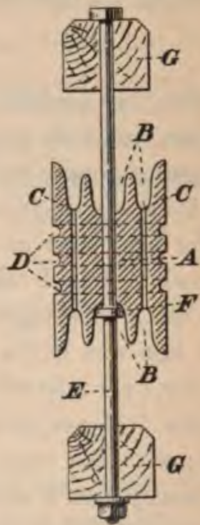

FIG. 9.

It, I am sure, requires no description to prove the superiority, mechanically, over the Bright's or ring, and more particularly over that form specially mentioned by the author.

Now with regard to the insulator itself, A = porcelain, B = channels top and bottom, C = three or four holes through, by means of which the channels are kept clear by rain, D = grooves for attaching wire of same size or varying sizes, E = bolt, F = collar on bolt to keep insulator in position, G = pole-arms. I claim that this insulator, as an insulator, has equal properties to that described in the paper. It must be admitted that the difficulty of insulation is caused by the surface being reduced by an accumulation of dirt, which, especially in wet weather, augments the leakage. Now in the majority of insulators the greater portion of this dirt exists in the channels, by the nesting of insects, webs, &c., which in wet weather absorb the moisture

Mr. Fletcher and form a ready communication to the bolt thence, and, especially with iron arms or earth-wired pole-arms, causing an appreciable leakage. I here again submit that with the shackle I have described this difficulty is largely done away with, owing to the passages C affording a free means in wet weather of cleansing the channels.

WIRE.

On this question I shall not only be at variance with the author, but with many others, because I prefer to stand by iron as against copper for line wire for railway work.

I have ever in my mind a phrase which came prominently under my notice at school, viz., "It is better to bend than to "break." This I take the liberty of slightly altering, and say, "It "is better to elongate than to break:" such are the conditions that iron wire fulfils, as against copper. A No. 8 iron wire giving 12 ohms per mile will elongate 15 per cent.; a copper wire, hard drawn, 0·75 per cent., or 20 times less: its tensile strength is less; with the same burden its breaking point is earlier. Consequently, iron is standing when copper is down; in fact, iron has a good deal left in it when copper is gone. If an iron wire is so allowed to decay before renewal that its tensile strength comes below the figures given by Mr. Langdon for copper, then the maintenance is worse than bad: destroy the outer skin of a copper wire and it comes down.

Then as to the electrical question, Does any railway company employ Wheatstone automatic telegraphy? My answer is, "No." Then the question of self or mutual induction does not come in, as no clerk can send, especially on the instruments which the author says are in general use on railways, so fast that they can affect the working.

Apart from railway work, I admit that for telephone companies copper wires are a necessity, for more reasons than one.

On a railway it is essential that your communication shall be continuous, especially for the block telegraph; but this is of little use unless your speaking telegraphs are available, for surely it is useless getting a train through to a certain station—say, for

instance, Crewe—and that through not having sufficient information you have such a block that it is impossible to despatch trains to their destination in anything like reasonable time. The block telegraph is an absolute essential, but to an equal extent so is the speaking telegraph, apart from telephones; and the only way to maintain both efficiently at present is a strong line of poles, and iron wire, with good maintenance. Mr. Fletcher.

Binding.

Fig. 9 in the paper is not what one would expect to be put forward as an ideal binder, as it is absolutely of no use so far as running back is concerned, except when the line wire is drawn in as shown by the following figure, which is as easy to effect as that described in the paper:—

Fig. 10.

Fig. 10 in the paper does not require such a provision, as the length of binder will bring about all that is necessary.

Underground Work.

On this subject I have nothing to say, except that for ordinary work it is so very hard to get at a decent price gutta-percha—and by "gutta-percha" I mean "gutta-percha," not some hybrid mixture called by that name—that it behoves engineers to use good vulcanised india-rubber insulated wire, laid up, either to an equivalent to 16s. or 18s., as may be required.

Instruments.

The author has mentioned the use of duplex telegraphy on various railway companies' systems, but has omitted from the list, the name of the London and North Western Railway Company; although I some time ago, in reply to an inquiry of his, informed him that we had in use a system of my own for duplex working,

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whereby we were able to work duplex or simplex at will, without any switching arrangement, and not only between terminal points of a circuit, but also between any point on the circuit, and at the same time to have ordinary simplex instruments on the same circuit, which work into each other or the duplex instruments as required. Below is an example of such circuits.

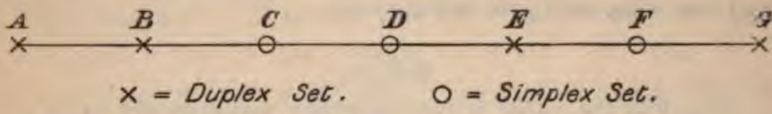

Fig. 11.

A can work duplex or simplex with B, E, G, or simplex with C, D, and F, and the others in like manner. I refrain from at present giving any detailed description, as I may bring the matter before the Institution in another way. It may be interesting to many to know that for some time, on one long circuit, we have been working a simplex repeater or translator, in conjunction with bell sounders and needles, giving most excellent results; and it is in anticipation to extend this arrangement to large transmitting centres, in order to relieve the office of transmitting work, especially at night, when the staff may be reduced to one or two, and at times, owing to a large influx of work, cause the work of the office to be congested. But we have not stopped here: we have at the present time in the works at Stockport a duplex repeater or translator, which is again simplex or duplex at will, working on an artificial circuit experimentally. This instrument is identical with the one previously before mentioned, and it is to take its place when it is possible to substitute simplex with duplex, at the various points on the circuit.

Signal Repeaters.

As the author says, signal repeaters and light indicators now play a most important part in railway telegraphs; in fact, to such an extent are they used, and to such a state of efficiency are they required to be maintained, that they to-day play as important a part as block telegraphs. As such is the case, it becomes necessary that they should be constructed on a

Mr. Fletcher.

thoroughly sound basis; and as it is evident that this increased use will considerably enlarge the total number of wires, if it is possible to work with one wire for both purposes, then it is expedient to do so, and not, as the majority of railway companies do, use two wires. I know that the author and others will here say, "But if you use one wire you are putting all your "eggs into one basket." My only answer is, In how many cases at the signal post have you a separate and distinct "earth" for light and arm where you have two wires, and also the same at the signal cabin? I am afraid the cases are very few or non-existent; therefore their case falls to the ground. If it is possible to obtain an instrument which will give the necessary indications with one wire, then use it. Such an instrument is to be found, and is in use at the present time, and has been for at least the last nine years, on the London and North Western Company's system. I will not go into details here, for reasons stated before, except that this instrument gives SIGNAL ON, SIGNAL OFF, and WRONG, LIGHT IN, and LIGHT OUT, with one wire, and battery of one cell. The contact makers and breakers in connection with the lamps play a most important part, and should be so constructed as to be perfectly reliable. Some time ago I took considerable pains in investigating the matter, and came to the conclusion that what had been done before was capable of considerable improvement. Bearing this in mind, I set to work, and have produced an "expansion tube"—for by such name it is known in the railway world—which fulfils all the necessary requirements. I have received up to the present very few complaints of the working of these tubes, although some 250 have been made. I refrain from going into details, as I am afraid that my criticisms and remarks will be longer than the paper; but I must say one word more. The author refers to the necessity of repeating other things in connection with signals than arms and lights; the instrument I have mentioned is capable, without any alteration, of doing this efficiently.

BATTERIES.

This forms so large a subject that I am afraid I should occupy

Mr Fletcher.

too much space if I attempted to go into the question even slightly, as I should differ with nine-tenths of the electrical world; and, therefore, it is preferable that the matter should be left alone, particularly as it would be an advantage if a paper was compiled on the subject, as I am sure that the discussion that would be provoked would be of the greatest interest, and it would not be fair for me to put forth points in this communication which could not be challenged.

Apologising for being so lengthy, I trust that the paper and these remarks may be the means of bringing some of the points mentioned more prominently before the Institution.

Mr. Clement.

Mr. A. F. CLEMENT (N. B. Ry. Co.) [*communicated*]: I am very glad to find such an able paper upon railway telegraphs brought before the Institution. It shows that the railway requirements have by no means been standing still, and that the electrical departments of railways have a very important part to play in the working of the enormous railway traffic which has been developed over the whole country. As regards the construction of telegraph lines on railways, I daresay most, if not all, of the companies follow very much on the same lines as Mr. Langdon. The severity of the storms of both wind and snow that we are visited by so frequently compels us to see to it that our telegraph lines will stand, and give the traffic departments a powerful aid in coping with the great difficulties of working traffic, especially during snowstorms, when the traffic gets quite disorganised.

The greater efficiency of railway telegraphs has not been attained without very great outlay, and I sometimes fear that the railway telegraph engineers do not get much credit for the many improvements effected.

The company that I have the honour to be connected with cannot show such an extensive development of their telegraphs as the Midland Company; still, they have kept pace with the times, and with their ever-growing requirements. With regard to the importance of railway telegraphs: Mr. Langdon's modesty has apparently prevented him from enlarging upon the extra responsibility thrown upon the telegraph departments. We have the Board of Trade ordering from time to time many appliances

that only a few years ago were never thought of. I should just like to mention that in connection with single lines of railway the safe method of working by train staff is fast becoming an obsolete system; it is too slow for the times. But by the ingenuity of Mr. Edward Tyer, who has introduced the electric train tablet system, and of Messrs. Webb and Thomson, who have introduced the electric train staff system, which serve both as a block telegraph and staff, we are enabled to work with the greatest safety an amount of traffic over single lines that without these would be practically impossible. The system of repeating line signals with duplicated mechanical signals has almost disappeared, and electric signal repeaters are substituted. Mr. Clement.

The lights of many signals also require to be repeated, so that, if a signal is duly lighted, and a small switch operated upon by the signalman in his cabin, he will get a visual or an aural signal (or both, if desired), should the signal light be extinguished. Indeed, on single lines, and to a great extent on double lines of railway, the traffic working almost entirely depends on the proper working of the electrical appliances; and I have no doubt that the far greater safety that has been attained in railway working is obtained through the improved electrical appliances that have been provided. There is no doubt that electricity is a most reliable agent; and given that those whose part it is to work the apparatus in conjunction with line signals do their part with the care that is necessary, and that is, generally speaking, attained, electricity scarcely ever fails.

In the message department, the growth of business conducted over railway wires will scarcely be second to the great growth of public message business of the country since the public telegraphs were taken over by the State in 1870.

I think I am safe in saying that many of the large railway companies individually send more messages, many of them very lengthy, over their own wires, than all the public telegraph companies combined sent on behalf of the public prior to 1870.

The President: It has long been an opprobrium to the Institution that we have had no papers from our railway telegraph engineers. Mr. Langdon has certainly removed that opprobrium; The President.

The President.

and he has done it, I believe, at some very considerable inconvenience to himself. His health has not been as good as could have been wished, and the paper has been prepared at a time when he has been far from well. Under these circumstances, I am sure you will all agree in according him a very hearty vote of thanks for the very valuable and interesting paper which he has read to us this evening.

The motion was carried by acclamation.

Mr. Langdon.

Mr. Langdon (in reply): I am sure all railway men will very much regret that the time at the disposal of the Council is so limited as to prescribe discussion in the present instance. It is also somewhat unfortunate that the days appointed for the meetings of the Institution frequently coincide with those days selected by most railway boards for their committees. It so happens that this is one of those days, and hence the representatives of the greater portion of the railways are not able to be here to-night. Mr. Wyles has spoken with reference to the progress of interlocking. There is no doubt that interlocking has progressed during the last three or four years to a considerable extent on the Great Eastern, the South Western, and on the Brighton Company's system. This interlocking is a most desirable thing; but it is to be somewhat regretted that railway companies, in undertaking it, should not have dealt with it in a more complete and definite manner. As I said in the paper, it is the first vehicle which relieves the lock on the section. A train entering a section puts on the starting signal automatically, and the block signals are put on by hand. Those block signals control the mechanical signals, and they remain locked until released by the train passing out of the section. If a train happens, from any cause whatever, to be divided during its journey, a certain portion of it remains in the section; but any one of the vehicles which pass over the releasing point when passing out of the section will enable the signalman to clear the section. Another train may then be admitted, and there might, of course, be a serious accident. Therefore I say that the present system is wanting in finality, and eventually something further *will have to* be done. It would be better for railway companies,

Mr. Langdon.

whilst they are about it, to deal with the matter in a more complete manner. That is to be done by attaching to the last vehicle of the train, at the station from which it starts, something which shall give this signal as the train passes out of the section. If that is done, then, should the last vehicle remain on the line, the section is not cleared. Mr. Wyles mentioned that electricity was rendering considerable aid in what he refers to as mechanical appliances—that is, it is taking the place of mechanical appliances; and that, I believe, is the case. Mr. Treuenfeld has also indicated that there is a large field for the application of electricity on railways. Undoubtedly that is so; and I believe it is only necessary for railway telegraph engineers to associate themselves with other branches of the service to find out those instances in which it may be useful, and so extend the field to which electricity may be applied. I am obliged to Mr. Goldstone for having corrected me with reference to duplex working on the London and South Western. Mr. Spagnoletti takes exception to the "H"-pole system. I think Mr. Spagnoletti has forgotten the diagonal tie-piece (Fig. 1). The very object of that block being placed *diagonally* across from one pole to the other is to prevent that scissors motion which Mr. Spagnoletti thinks would arise. With reference to the poles (Fig. 2), of course there is nothing to prevent one pole sinking into the soil more than another; and it was for that reason I pointed out the desirability of allowing the newly planted pole to stand some days before you consolidate the structure by putting on the cross-arms. The fact is that, although we have erected some hundred miles of these poles, we seldom find one pole sinks more than the other. I do not claim any credit for the design, because I believe it has been done by others before me, although not, perhaps, to any great extent. Mr. Spagnoletti has remarked that the stay-rods sometimes pull through the blocks. I never knew them do so unless the blocks were thoroughly rotten. With all stay-rods a plate or washer is provided, against which the head of the rod rests. That ought to prevent the rod drawing through the block unless it is rotten.

Mr. Spagnoletti: I referred to wooden ones.

Mr. Langdon.

Mr. LANGDON: If they are creosoted they ought not to rot. With reference to lateral staying, although I have not referred to it in the paper, I have pursued that practice for many years. When I first went on the Midland we had a serious breakdown on the Settle and Carlisle line, and the poles and wires ran back in the manner indicated by Mr. Spagnoletti. I thereafter adopted lateral staying at every tenth pole, where the number of wires on the pole exceed 20. Mr. Spagnoletti mentioned that he has had experience of iron wire lasting 35 years. I heartily congratulate him. I wish we could get wire to last 35 years. Difficulty in the handling of copper wire has been referred to. I do not experience that difficulty. The men under my direction find no difficulty in erecting copper wire. They have to be careful that they do not, in making the joints, burn it. They have their tension tables, with directions as to the strain they may place upon the wire when pulling it up: they comply with these directions, and there is no difficulty whatever. There is no question, as Mr. Spagnoletti points out, that the shackle affords a much more direct hold upon the wire than a terminal insulator. There is not that leverage about it, because with the former the strain comes direct on the bolt; but it is, at the same time, an inferior insulator. Mr. Spagnoletti may be correct with regard to the "leading-in" cups, although I do not remember their being used at the time he mentions. With regard to wire steeped in boiling tar, it occurs to me that the value of tar as a preservative lies mainly in the oil which it possesses; and certainly, when that oil evaporates, as it will under the influence of the sun, there will be nothing but a sediment left, which would prove a very poor protection, I am afraid. At the same time, I must admit I have not heated any wire and steeped it in boiling tar. We have enjoyed the use of the phonopore only to a limited extent; and if Mr. Spagnoletti, or those who have the phonopore in their hands, could only prevent its inductive influence upon neighbouring wires, it would be an excellent instrument. This induction interferes with our telephone circuits, and we get no end of complaints. In reply to Mr. Charles Bright, gutta-percha wire has been used for a great many

years. I think it probable that in many instances india-rubber would be equally serviceable, but I am under an impression that india-rubber wire becomes somewhat plastic when exposed to the air. The life of gutta-percha-covered wire is extended by the wire being covered by ozokerite tape; that is, it protects it from the effect of the atmosphere. Unprotected gutta-percha wire exposed to the air soon becomes dry and resinous, and then possesses little, if any, insulating power. If you could keep gutta-percha always in water, undoubtedly that would be the best thing for you to do; but in respect of railway requirements that would be an impossibility. Mr. Treuenfeld has called attention to iron poles. Iron poles have been tried to a limited extent on railways; but they are not, as a rule, strong enough for our purpose, unless you incur great expense—such an expense as would be wasteful in comparison with the cost of creosoted poles. Mr. Treuenfeld objects to copper wire as compared with iron wire, and he has endeavoured to strengthen his argument by directing attention to the effect which snow, when clinging to the wires, would exercise. It is very strange, but I have noticed that after a snowstorm there is very little difference between the amount of snow on an iron wire and a copper wire, although the one may be of larger section than the other. The experience we have is that copper wire stands quite as well as iron wire in snowstorms. It seems somewhat inconsistent that such should be the case, but we find that even No. 14 copper wire will stand as well as a larger gauge iron wire.

Mr. Langdon.

In responding to the remarks which have been *communicated*, I avail myself of the opportunity to reply more fully on some of those questions raised by speakers who took part in the limited discussion, and to whom my rejoinder was, owing to the late hour, scarcely so complete as I could have desired.

In referring to the progress made in the interlocking of the electric with the mechanical block signals, I am sorry to find I omitted to make reference to that which had been done on the London, Chatham, and Dover line, as well as that on the Metropolitan. The Chatham and Dover was, of course, the field which Mr. Sykes first laboured in this direction, and, natura

Mr. Langdon.

has reaped to a large extent the advantage of his experience. No railway system can more thoroughly need the additional protection afforded by this interlocking than the Metropolitan Railway, with its enormous concourse of trains and endless flow of passengers.

Some surprise has been expressed that the subject of interlocking has not been more fully dealt with in the paper. It has apparently been forgotten that the scope of the paper would not admit of anything beyond the casual reference made. The object of that reference was not only to direct attention to the progress which had been made, and to its utility, but also to point out that, in the author's opinion, that which was being done was still wanting in finality. The suggestion thrown out by me in my remarks on the discussion, that this may be accomplished by applying to the last vehicle of the train that which alone shall give the clearance signal on the train passing out of the section, is contested; but I feel bound to say that I do not see any other means by which this may be accomplished, otherwise than by the adoption of some such method as that employed in the "Hall "system," under which the presence of any vehicle on the rails places the signals automatically at "danger." It must be clear to everyone acquainted with railway signalling, that the present method of interlocking the electric with the mechanical signals does not provide for a portion of a train being left behind in a section. It may be the duty of the signalman to see that every train passes out of the section complete, but that is not the point: the block signalling arrangements should be such as to render it impossible for the section to be cleared until the *entire train* has passed out of it. I am, perhaps, wrong in using the expression "finality," but I believe it will be understood in the sense in which it was employed by me—relatively to that which is being done.

I regret very much I was not able to reply more fully to Mr. Chas. Bright's remarks anent gutta-percha *versus* india-rubber insulated wire. I infer Mr. Bright is under the impression railway companies are large users of underground wires. This is not so. In places wires have *perforce* to be

laid underground, but wherever this can be avoided it is done. Mr. Langdon. Wooden boxing attached to retaining walls is preferred as being more accessible for renewal or increase of wires. The chief source of consumption of insulated wire is signal-box work. An ordinary signal box will call for from a third to half of a mile of wire; larger boxes, from half a mile to a mile or more. It is in this work that depreciation arises—where the wires are exposed to the evaporating influence of the atmosphere. The gutta-percha, if unprotected, soon loses its insulating properties, becomes dry and resinous, and readily cracks. If covered with tape steeped in Stockholm tar, its life will be extended; but tar soon loses its protective power: the oil is vaporised, and a rough sediment alone remains. The tape readily leaves the gutta-percha, and it, in turn, soon succumbs. But if it be encased in ozokerite tape, properly laid on, this result will not be achieved nearly so soon. The ozokerite tape does not perish so readily. It is for this reason I suggest the use of ozokerite-taped gutta-percha wire. I know but one objection to ozokerite taping. To be well laid on it must be applied at considerable heat, and, consequently, unless carefully dealt with, there is a liability of the conducting wire becoming decentralised.

Gutta-percha wire has been used for many years with general convenience. It is easily manipulated, and the mode of jointing is fairly understood by those who have to handle it. Vulcanised rubber, as now manufactured, will probably prove as, if not more, durable, but there will be greater difficulty in dealing with joints. Possibly plain rubber joints would meet the requirements of signal-box work—where the joints are not exposed to moisture. For cables, the author has made use of it with advantage, and is now laying in a long length for tunnel work. Pure rubber insulation he has, as stated in the paper, used, with, he believes, some success, for signal-post work.

Mr. Spagnoletti has expressed the view that it would be better to place the lower cross-piece of timber which ties the H-pole structure together at the foot of the two poles, under, rather than bolted to the sides of the poles, so as to give the structure a "r "substantial foundation for the pole." There is, I cannot

Mr. Langdon.

thinking, an absolute advantage in bolting this cross-piece on to the side of the poles. So long as the bolts which fix it to the poles are good, the structure will get its foundation bearing from this plank just as well when bolted on to the side of the poles as when the plank is placed underneath the butts of the poles; and it will probably last longer. A further objection to the method proposed by Mr. Spagnoletti may, perhaps, be found in the fact that should this cross-piece, when fixed to the butts of the poles, become rotten, it would either displace the structure, or cast an additional strain upon other portions of it. I must admit I am in favour of adhering to the practice advocated in the paper.

Creosoted stay-blocks are practically indestructible when laid in the soil. They should be bored for the reception of the stay-rod before being creosoted. They ought to be cheaper than cast-iron, surface for surface. A railway sleeper will cut into three stay-blocks, affording, as a rule, a surface resistance of some 300 square inches. Second-hand sleepers, cut and bored, and re-creosoted, are good enough for the purpose.

I am in doubt whether the form of leading-in cup employed by me is the same as that referred to by Mr. Spagnoletti; in fact, I am quite sure it is not. Even if a somewhat similar form of leading-in cup was in use at the date referred to, it differed from that employed by me in that it did not possess the openings in the iron hood provided to admit of the cleansing effect of rain; nor was provision made in the porcelain tube for centralising the leading-in wire, and thereby preventing surface leakage at the edge of the tube. These are, perhaps, not very important points, inasmuch as the number of terminations on wires are not numerous; still, they mark an improvement.

I never knew the West's covering of iron wire to fray, provided it was carefully and properly erected. When run out it should be passed through a piece of leather lightly held by the man in charge of the wire-barrow. This will remove any rough excrescences, and in a short time after exposure to the atmosphere the covering will be both smooth and hard. It is important wire so covered should not be run too tight.

My best reply to the criticisms on the use of copper wire

versus iron wire is, I think, the fact that No. 14 copper wire erected on the Midland in 1878–79 is still, to all appearance, as good now as when put up. At that date the manufacture of copper wire for telegraph purposes was not so well understood as is now the case, still the wire is there; it is in smoky localities, where iron wire would have corroded in less than 10 years. In its erection at that date little was known as to its treatment—the burning of joints, stress, and so forth. If men could then deal with it so as to produce such satisfactory results, surely with our present experience there should be no difficulty. Mr. Langdon.

Mr. Treuenfeld has mathematically shown how utterly worthless a No. 14 copper wire must be in a snowstorm, with ice adhering to the wire, when compared with a No. 8 G.I. wire. Mr. Treuenfeld has taken the breaking strain of the latter somewhat above that now specified for in good conductivity wire; and, again, in copper, has taken it at slightly less than can be obtained with hard-drawn conductivity copper wire. The Post Office present specification for G.I. wire, 400 lbs. to the mile, 7½ gauge, is a stress of 1,075; for 100-lb. copper (No. 14), a breaking strain of 330 lbs.; and for 150-lb. copper (12½), a breaking strain of 490 lbs. As previously observed, there is in existence on the Midland lines a large mileage of copper, much of which has been in use for several years. Snowstorms have passed over it, and it has stood the test of one of the most severe winters experienced in England. I cannot say that it has stood better than iron wire, but it certainly has not fared worse. There are two important factors which contribute towards this result, and which, I fear, are not sufficiently borne in mind. A copper wire of No. 14 or No. 12½ gauge is, of course, considerably smaller than a No. 8 gauge iron wire. The mass of metal is less. Its power of retaining heat is less. When the atmospheric condition is such as to encourage falling snow to cling to the wires, the condition is this: The wire is slightly warmer than the falling snow; the heat stored up in the wire melts the snow which first falls upon it, when, the wire becoming chilled, the melted snow is formed into ice. According to the degree of warmth in the wire so w the snow be melted and cling to, or fall from, the wire.

n:don,

condition is a peculiar one. If there is much heat in the wire the snow will not cling for a long time; but if the snow is persistent a moment arises when the temperature of the wire is chilled to such an extent as to convert the half-melted snow into ice. We can understand how the rapidity of this chilling governs the formation of the ice—whether forming of it a mere shell, or, as is sometimes the case, a solid mass of ice from 1 to 2 inches in diameter. Now under these conditions the *mass* of the metal must play an important part. In the No. 8 gauge there will be stored up a greater reserve of heat than in the No. 14 or No. 12½. Again, copper is a more ready conductor of heat or cold than iron; *i.e.*, it responds more readily to varying temperatures. The copper (smaller) wire has less surface on which the ice can form; less mass in which to conserve its temperature: it has, consequently, less heat stored up; and it, being a more ready conductor of heat, more speedily loses what it may have possessed, and assimilates itself to the surrounding atmosphere. I believe it will be found that copper wire will not accumulate ice to the same extent as iron wire—gauge for gauge—but I think there can be no doubt that No. 14 or No. 12½ will not do so to any degree in comparison with No. 8 G.I. wire.

In this, then, provided my argument is correct, we have one reason why these small copper wires resist snowstorms as well as iron wire. In considering the question thus far, I have regarded it from the standpoint of new wire. When iron wire has depreciated to that gauge where it calls for renewal, No. 12½ copper has the advantage of it in every way, and, I believe, No. 14 also. There are climatic conditions to which the best of wires succumb. Those conditions entail breakage of something—poles or wires—and, as I have suggested, it is better for the wires to go than for the poles.

I am very sorry I could not, as Mr. Hampson has suggested, enter more fully into the various kind of apparatus in use on railways. I fear the paper was, from its length, a tax upon the patience of the meeting. I hope, however, that, the subject of telegraphs having again come under the notice of members, we may in the ensuing session have other papers under the same head.

I quite appreciate, as no doubt will others, Mr. Hampson's remarks and suggestions in respect of light indicators, and feel that those remarks will, no doubt, prove fruitful. Mr. Langd

I fully concur with Mr. Clement in his observations on the increasing responsibility of the electrical department of a railway. Every day shows its utility, and day by day fresh channels for its employment are presenting themselves to our view. It would be interesting to know the number of messages which pass over the railway wires in a year. The number of forwarded messages dealt with by the Midland for the past year was 4,718,251, and the total number of transactions—that is, forwarded, received, and transmitted, the latter being counted double—was 14,932,423.

At the moment of closing these observations, Mr. Webb, our secretary, has been kind enough to forward me the remarks of Mr. Fletcher, jun. I have nothing to say to them, beyond that apparently we may shortly look for some interesting developments on the London and North Western Railway. I regret that in the original proof, or in the manuscript, the South Western, instead of the North Western, was referred to as employing duplex. The error has now been corrected.

The PRESIDENT announced that the scrutineers reported the following candidates to have been elected:— The Presid

Associates:

Fred. A. Donnison.
Leo Arthur Hards.
James Leggat Kilpatrick.
F. A. B. Lord.
Ernest Wilmot Rees.
Louis Schramm.
William Wyld.

Student:

Edward A. Short.

The meeting then adjourned.

ABSTRACTS.

A. RIGHI—NEW EXPERIMENTS ON THE GLOBULAR SPARK.

(L'Éclairage Électrique, Vol. 6, No. 8, February, p. 362.)

About four years ago, the author discovered that the discharge from a large condenser may in certain cases, and under suitable conditions, produce a phenomenon* characterised by a luminous effect, taking place near the positive electrode. This increases in dimensions, leaves the electrode, and travels at a comparatively slow rate towards the cathode, which, however, it never reaches. Sometimes a compound discharge takes place, consisting of several discharges in succession. The author has called the above effect the "globular discharge."

One condition necessary for producing these effects, is that the discharge circuit should have a very high resistance, which is realised by introducing a column of distilled water in circuit. By using a condenser of large capacity and suitably rarefying the gas, the dimensions of the spark and the distance through which it travels will be increased.

The velocity of the luminous mass varies according to circumstances; and with high velocities the spark, viewed directly, will not appear to differ from an ordinary spark; it is only by viewing its image in a revolving mirror that one observes the globular effect. With a simple discharge and a velocity of, say, 1 metre per second, its presence and movement are directly perceptible.

In these researches the author has endeavoured to render the motion of the luminous mass as slow as possible, and at the same time to increase its time of duration, and for this purpose it was necessary to use a condenser of large capacity.

About 0·075 M.F. was obtained from a battery of 108 Leyden jars connected in series, these being charged from a Holz machine driven from a motor. The discharge circuit consisted of a spark micrometer, an adjustable distilled water resistance, and the discharge tube, containing a more or less rarefied gas. On account of the large influence which the dimensions of the tube have on these phenomena, and for the purpose of eliminating all complications. the author employed in the greater number of experiments tubes of equal dimensions, 38 cm. long and 4 cm. diameter, fitted with electrodes of platinum or aluminium wire. When the battery potential attains a sufficiently high potential, a spark passes between the balls of the exciter, and the phenomenon is then observed in the tube.

With high resistance and high capacity the duration of the phenomenon may exceed 1 second. As the resistance of the column of water is altered the spark in air is of the second, third, or fourth type, and produces in the two latter cases a shrill and prolonged whistling sound.

The author has frequently employed another method producing discharges

of still longer duration. It is known that with sparks of the first order—*i.e.*, ordinary sparks—the time of duration is so short that a movement imparted to its electrodes has no sensible effect on its time of duration. This is, however, not the case with a high resistance in circuit, and it is possible in this case to alter the distance between the two balls during the presence of the spark. By this means, the discharge may have a long duration, which increases when the potential, capacity of condenser, and resistance of circuit increase. It is easy to judge of the duration of the discharge by employing a small auxiliary spark gap in the discharge circuit, in which case the duration of discharge increases when the length of this gap is diminished.

The prolonged discharge seems to behave in the same way as an electric current of which the intensity increases rapidly at first, then more slowly up to a maximum value, to then diminish and finally die away.—(*To be continued.*)

H. BECQUEREL—ON THE INVISIBLE RADIATIONS EMITTED BY PHOSPHORESCENT BODIES.

(*Comptes Rendus, Vol.* 122, *No.* 9, *March, p.* 501.)

The experiments carried out by the author on the invisible radiations emitted by phosphorescent bodies were made with crystalline slips of the double sulphate $S\,O^4(U\,O)\,K + H^2\,O$, of which the phosphorescence is very active, and the duration of persistent luminosity less than 1-100th second. It is found that the radiations emitted by this substance, after exposure to sunlight or diffused daylight, not only pass through sheets of black paper, but also through certain metals, such as aluminium and thin sheets of copper.

The experiment was made by exposing to direct sunlight a photographic plate enclosed in a dark slide consisting on one side of an aluminium plate. Under these conditions no effect was detected; but if on the exterior of the aluminium plate there be placed a slip of the uranium salt, it is then found that its silhouette appears on the plate after an exposure of several hours to sunlight. If there be placed between the slip of uranium salt and the sheet of aluminium a piece of copper about 10 mm. thick, and cut to a certain shape, its image will appear on the plate with a lighter tint, but showing that the radiations have passed through the copper. The phosphorescence produced by sunlight reflected from the metallic mirror of a heliostat and then refracted by a prism and a quartz lens gave rise to the same phenomena.

The following experiment is of considerable importance:—The same crystalline slip, under the same conditions as the above, but sheltered from the source exciting the radiation, and placed in the dark, was found to still produce the same photographic effects. The experiment was performed by enclosing a photographic plate in a thick cardboard box and placing on its sensitive face a slip of uranium salt of convex shape, and thus only touching the film at several points. At the side of this, and on the same plate, was placed a second slip of the same salt, separated from the surface of the gelatino-bromide by a thin film of glass; the experiment being performed in perfect darkness. The same was done with a plate enclosed in a dark slide, one side of which consisted of a sheet of aluminium on which were placed the slips of uranium salt.

After five hours, the plates were developed, and the images of the slips appeared as before, in the same manner as when the slips had been rendered phosphorescent through the action of light. With the convex piece which was placed directly on the gelatine, there was practically no difference in the action between the points of contact and those parts which were about 1 mm. distant from the gelatine. The action of the slip placed on the sheet of glass was very slightly weakened, and its shape was very sharply reproduced. The effect through the sheet of aluminium was considerably weakened. The author observes that this phenomenon does not appear to be attributable to luminous radiations emitted by phosphorescence, as after 1-100th second these radiations have become so weak that they are scarcely perceptible. The author's hypothesis is that these radiations, of which the effects are very analogous to the radiations studied by MM. Lenard and Röntgen, may be invisible radiations emitted by phosporescence, and of which the duration of persistence would be infinitely greater than the duration of persistence of luminous radiations emitted by this body.

A. D'ARSONVAL—OBSERVATIONS ON THE SUBJECT OF PHOTOGRAPHY THROUGH OPAQUE BODIES.

(*Comptes Rendus, Vol.* 122, *No.* 9, *March, p.* 500.)

Amongst those who have endeavoured to reproduce M. Le Bon's experiments, some have obtained positive results, and others no image whatever.

After repeating these experiments, the author finds that both results are correct, everything depending on the conditions of the experiment. In operating as did Mr. Lippmann—*i.e.*, by exposing to the solar rays a sensitive plate protected by a metallic screen—no result was obtained, even when the plate consisted of a very thin sheet of aluminium. The metal is then not traversed by the solar rays; which contradicts the results obtained by M. Le Bon. This is, however, not the case if one interposes between the metallic plate and the solar rays a piece of thick plate glass. Under these conditions an impression is observed on the plate. If a piece of uranium glass be placed on the metallic plate, the impression takes place more rapidly; the best glass being that which shows a greenish yellow fluorescence when illuminated in the dark by an electric spark This also applies to tubes employed for producing Röntgen rays.

All incandescent lamps which give a greenish yellow fluorescence can be used in the place of Crookes tubes; those, on the contrary, giving a violet or blue fluorescence produce practically no results.

The author obtained equally good results with a Geissler tube surrounded with a solution of fluorescence.

The conclusion, therefore, to be derived from these experiments is that any bodies which emit fluorescent radiations of a greenish yellow colour, are capable of acting on photographic plates through opaque bodies.

Fluorescent bodies emit radiations possessing the properties of the x rays, according to M. Poincaré's hypotheses. From these facts, it appears as though the cathode rays in the Röntgen experiments, excite fluorescence in the glass *forming* the Crookes tubes.

MM. BLEUNARD and LABESSE—ON THE PASSAGE OF THE RÖNTGEN RAYS THROUGH LIQUIDS.

(*Comptes Rendus, Vol.* 122, *No.* 9, *p.* 527.)

In order to study the influence of liquids on the passage of the x rays, it is necessary to be free from the errors due to the influence of the containing vessels. The authors have found that black paper smeared with tallow is quite transparent to these rays. Their experiments were made by wrapping up the photographic plates in black paper and placing on them small trays of greased paper, containing equal layers of the different liquids. The impressions obtained on the plates are then entirely due to the opacity of the liquids.

It is found from preliminary experiments that water is easily traversed by the Röntgen rays, while solutions of bromide of potassium, chloride of antimony, and bichromate of potash offer a great resistance to the rays. Solutions of sodium borate and permanganate of potash are more easily traversed. Colour seems to have no effect on the passage of the rays; water coloured with different aniline dyes offers no resistance.

A. IMBERT and H. BERTIN-SANS—DIFFUSION OF THE RÖNTGEN RAYS.

(*Comptes Rendus, Vol.* 122, *No.* 9, *p.* 524.)

During experiments made with the intention of increasing the intensity of the Röntgen rays, the author noticed very marked diffusion phenomena, the presence of which may be of help in determining the nature of the new rays. To verify the presence of diffusion the rays emanating from a Crookes tube were made to fall on flat strips of various substances. The photographic plate was placed at the side of the Crookes tube in a position about normal to the direction of the beam, if reflected regularly. A thick sheet of copper was interposed between the Crookes tube and the photographic plate, in order to screen the latter from all direct radiations. The authors conclude that, if the Röntgen rays are reflected regularly under the conditions of these experiments, they only do so in a very weak proportion; per contra, they can be diffused pretty largely, and the intensity of diffusion appears to depend far more on the nature than on the degree of polish of the diffusing body. This suggests a very short wave-length for these rays, and such that it becomes impossible to determine the degree of smoothness necessary to realise regular reflection.

From the negatives obtained with cork, which is transparent to these rays, and quartz, which is opaque, it was discovered that their transparency differs with the nature of the rays diffused by different substances.

The authors have commenced a series of experiments on this effect, from which they hope, either by diffusion or by transmission, to obtain information on the nature of the beam of the new rays.

HENRI BECQUEREL—ON A FEW NEW PROPERTIES OF THE INVISIBLE RADIATIONS EMITTED BY DIFFERENT PHOSPHORESCENT BODIES.

(*Comptes Rendus, Vol.* 122, *No.* 10, *March, p.* 559.)

Action on Electrified Bodies.—The author finds that the invisible radiations emitted by the uranium salts, and particularly with the double sulphate of uranium

and potassium under the conditions of his recent research, have the property of discharging electrified bodies submitted to their action. The experiment is simply made by substituting a slip of the double sulphate of uranium-potassium in the place of the Crookes tube, employed in MM. Benoist and Hurmuzescu's experiment.

The Hurmuzescu electroscope, when protected against external electric influences by a metallic shield, and against ultra-violet radiations by yellow glasses, will remain charged for months. If one of the yellow glasses be replaced by a plate of aluminium 0·12 mm. thick, and against the outside of this be placed a slip of the phosphorescent substance, the gold leaves of the electroscope will be seen to slowly converge, indicating a gradual discharge.

One of the tests, showed that a charge which produced a deviation of about 18° was dissipated in 2 hours and 56 minutes.

More rapid results were obtained by placing the radiating substances directly below the gold leaves.

A slip of the salt measuring 45 mm. by 25 mm. was placed in this position, with a deviation of the leaves of 12°: the discharge took place in 25 minutes with a negative charge, and in 23 minutes with a positive charge. The same charge was dissipated in an hour and 48 minutes with the slip placed behind the aluminium sheet. When placed above the leaves the action is considerably slower.

Reflection and Refraction.—The reflection of these invisible radiations was evidenced by the following experiments:—A slip of the uranium salt was placed on a sensitive gelatine plate, and half the former was covered by a steel mirror of which the polished surface was turned towards the slip and the photographic plate. After 55 hours the plate was developed, and showed a very strong image, with sharp edges of the half of the slip which was uncovered by the mirror; the other half, however, had diffused edges, and appeared as though superimposed with a second image produced by a second slip placed at some distance from the gelatine.

Another experiment on reflection was also made. A hemispherical mirror was cut from a small block of tin. In its focal plane was placed a crystalline slip with a triangular shaped end, which occupied a sector of the base of the polished mirror. This arrangement was placed on a sensitive plate, the mirror having its concave side turned towards the plate, the crystalline slip being separated from the latter by a piece of paper. The plate was developed after 46 hours, and showed a silhouette of the crystalline slip with its triangular end surrounded by an obscure circle, in which could be observed the image of a fault in the mirror. This halo, with somewhat sharply defined edges, is, then, due to radiations, which, after having fallen on the mirror, have been reflected on to the plate in fairly parallel directions.

In his experiments on refraction, the author has observed indications of refraction of these rays, through a prism.

Effects produced by different Substances, and the Duration of Emission in the Dark.—A first series of experiments consisted in placing on the same photographic plate different compounds—sesquioxide of uranium; double sulphate of uranium and potassium, of sodium, of ammonium, forming thin crystalline layers; also a crystal of nitrate of uranium, and a piece of very phosphorescent hexagonal blende. The plate was wrapped up in black paper, and the substances each fixed

on a slip of glass 0·2 mm. thick. In the case of the nitrate it was necessary to protect it from the effect of atmospheric moisture by placing a small glass cover over it, cemented to the lower plate with paraffin wax. These substances, which had long previously been subjected to the action of diffused light, were left in total obscurity for 48 hours, after which time the plate was developed, and the images thereon showed about equal effects for the different salts of uranium under study, but the hexagonal blende manifested no action.

The same substances were arranged on a similar plate and under exactly similar conditions as in the last experiment. They were screened from daylight and exposed to the light of a distant candle for 45 hours. The images obtained, were as sharp and as intense as in the last experiment.

It is important to note that, after having been kept for over 160 hours, the intensity of the radiations emitted by these substances in the dark had not diminished to any sensible degree. In the preceding experiments, the images of the crystalline slips have sharp edges on account of the thinness of the latter. The image of the crystal of nitrate of uranium was surrounded by an obscure region, limited by the contour of the glass cover. This effect was due to the action of the radiations emitted obliquely from the vertical faces of the crystal: the radiations stopped by the glass were completely refracted and reflected; the action being strongest in the regions which were in contact with the crystal of nitrate of uranium.

In another series of experiments, various phosphorescent sulphides were placed on a photographic slide containing a photographic plate, and enclosed by a sheet of aluminium 2 mm. thick. The sulphides were enclosed in glass tubes, and, after exposure to diffused light, were placed in a dark box.

The plate was developed after 43 hours' exposure. Hexagonal blende produced no effect, neither did orange sulphide of calcium or sulphide of strontium; but the blue and bluish green sulphides of calcium produced strong effects—the strongest yet obtained in these researches. Experiments were then made to ascertain whether thin layers of air do not absorb these rays to a marked degree. Slips of double sulphate of uranium and potassium were placed on a photographic plate at distances of 0·0 mm., 0·2 mm., 1 mm., and 3 mm. from the film. A second plate was prepared in the same way. One was kept in air and in the dark, and the other, also placed in the dark, was kept in a rarefied atmosphere. The plates were developed after 23 hours' exposure, and there was practically no difference between the relative images on the two plates. The images of the slips in contact with the gelatine to that 1 mm. distant were almost similar, but the image of the one 3 mm. away from the gelatine was much weaker than the others on both plates.

H. PFLAUM—ON A CROOKES APPARATUS.

(*Wiedemann's Annalen, Vol.* 57, *No.* 3, *p.* 443.)

In order to show the difference between the electric discharge in a moderately and a highly exhausted space, Crookes has employed, amongst other apparatus, two pear-shaped glass bulbs, numbered 7*a* and 7*b*, which were exactly similar in shape, and only differed in the degree of exhaustion. Whilst the air in the first

bulb had a pressure of some millimetres, the second bulb was almost completely exhausted (according to Crookes, to a pressure of one-millionth of an atmosphere). In the bulbs were fused three pointed electrodes, A, B, C, and a concave electrode, K. When the electrodes A, B, and C in bulb *7a* were successively made the anode, while K remained the cathode, a violet stream of light was seen to pass from the cathode to the anode in each experiment. When the experiments were repeated with bulb *7b*, another phenomenon took place, which was the same whether A, B, or C was the anode. From the concave cathode streamed a pencil of reddish violet rays converging to the centre of the mirror, and which diverged from the centre to the opposite wall of the bulb, where an especially brilliant phosphorescence of the glass was produced.

The above results were repeated by the author, who obtained similar results to Professor Crookes with respect to bulb *7a*; but with bulb *7b* somewhat different results were obtained, as follows :—

On making K the cathode, and A, B, or C the anode, a yellowish grey stratified light was seen extending from the anode to the cathode, whilst the cup-shaped cathode was entirely covered with a bluish white light.

By careful observation the following details could be distinguished :—Directly over the cup-shaped cathode was a layer of white light about 0·8 mm. thick, which was very clearly perceptible at the back of the cup. Next to this was a darker layer of similar thickness. On this darker layer was another clear white layer of 1 to 1½ mm. thick, and up to this there extended a dull light that became gradually fainter, and extended behind the cathode as far as the glass wall of the bulb; whilst in front of the cathode it extended to nearly a centimetre, becoming gradually fainter. Towards the anode this luminosity ceased at the "dark space," beyond which there were 12–15 concave yellowish grey luminous discs, in active vibration, towards the anode, these discs being of unequal thickness and distance apart. This stratification was on both sides of, or interrupted by, a very faint dark violet luminosity. The layers forming the stratification nearest the anode appeared to lie so close together that they became almost indistinguishable in a dull grey steady luminosity which extended behind the pointed anode. In the middle of this luminosity was the anode, surrounded by a brighter layer enclosing a darker layer. Directly over, or on, the anode there was a very bright white aureola, the light of which appeared to be also unsteady or flickering. The effects were substantially the same whichever of the three anodes was employed.

The luminous effects produced when the cup-shaped electrode was made the anode, were also observed. The cup-shaped anode was then again surrounded, as the cathode was in the previous experiment, by a luminosity in which the same parts could be distinguished. Close to the dark space there was in this case a continuous luminosity that was always brighter towards the cathode. The pointed cathode had in this case the same appearance as the pointed anode in the previous experiment; that is to say, round the flickering aureola there was a darker, and round this a brighter shell. There was in this case no stratification; the fluorescence of the glass remained the same as before. Now and then a spark was set free from the cathode, when a vibration was observable *in the luminosity* between the cathode and the dark space.

H. USENER—ON THE GENERATION OF ELECTRICITY BY FLUID CURRENTS.

(*Beiblätter, Vol.* 20, *No.* 3, *p.* 205.)

A cylindrical iron bell was stood in a porcelain dish in an inverted position and closed by a water seal. In the upper part of the bell was arranged a mercury-drop electrode, the outlet orifice of which was in the centre of the bell, and which served for measuring the electrification of the air, and also a long adjustable glass tube for conducting the stream of water. For obviating as much as possible the friction of the stream at the outlet orifice, the glass tube, which was somewhat expanded towards the bottom, was closed by a metal cone with a fine opening. Both the height through which the water stream fell, as well as the velocity at which it issued from the orifice, could be varied, the latter adjustment being effected by altering the head of water. The stream of water impinged on a plate mounted inside the bell. The results were as follows:—

1. Falling drops electrify the air, since they are surrounded by an adsorbed gaseous envelope which increases the like and opposite charges thereto; this gaseous layer is stripped off by the fall as an impediment, and becomes free in the air, which shows a charge.

2. This formation of a double electric layer requires a measurable time to develop.

3. This time depends on the velocity of the drop relatively to the air.

4. The quantity of electricity which becomes free in the air is, however, independent of the velocity with which the drops fall.

5. Increase of temperature produces a stronger electrical action.

6. The part of the gaseous layer which passes electrified into the air is at the under side of the drop.

7. The gaseous envelope must be in an electrically dissociated condition; the degree of dissociation is dependent on the matter dissolved in the water, both as regards its quantity and its nature, since the ions in the water directly influence the electrification of the gas.

G. FERRARIS—REPORT ON A TREATISE OF L. LOMBARDI: "POLARISATION PHENOMENA IN A HOMOGENEOUS "ELECTROSTATIC FIELD."

(*Beiblätter, Vol.* 20, *No.* 3, *p.* 206; *Atti. R. Acc. delle Scienze Torino*, 30, *pp.* 512–514, 1895.)

The work to be mentioned here is an extension of the researches of L. Graetz and L. Fomm on the turning moment which thin discs or rods of different substances experience in an electrostatic field. The poles of an accumulator battery between which there was a P.D. of 21,000 volts, which could be made alternating by means of a rotating commutator, were put into communication with two insulated vertical metal plates; in the electrostatic field between these plates there were arranged discs of metal or dielectric material by means of a bifilar suspension. In each case the author found that the turning moment varied as the

square of the force in the electrostatic field. He also points out that his arrangement is suitable for both relative and absolute quantitative measurements, and for the determination of dielectric constants.

P. PETTINELLI—WHETHER ELECTRIFICATION IS PRODUCED BY THE VAPORISATION OF VARIOUS CONDUCTING AND VERY FLUID LIQUIDS.

(*Beiblätter, Vol.* 20, *No.* 3, *p.* 207; *Nuov. Cim.* (4), 2, *pp.* 36–38, 1895.)

The author could not detect any electrification caused by the vaporisation of ethyl-alcohol and ethylic ether (which was made conducting by the solution therein of bromides) of acetone, allyl-aldehyde, and propyl-aldehyde, using insulated nickel plates connected to a condenser and a quadrant electrometer, the nickel plates being either at the ordinary temperature or previously heated to 100 degrees.

F. OETTEL—ON THE ELECTROLYTIC PREPARATION OF MAGNESIUM.

(*Beiblätter, Vol.* 20, *No.* 3, *p.* 210; *Zeitsch. f. Electrochem.*, 2, *pp.* 394–396, 1895–1896.)

For the preparation of magnesium, carnallite is heated until all the water is driven off; it is then heated strongly in a graphite crucible with carbon, whereby it is reduced to Mg O. Finally, the Mg O is decomposed by an electric current in a melting pot or vessel which at the same time serves as the cathode.

G. VORTMANN—ELECTROLYTIC DETERMINATION OF THE HALOGENS.

(*Beiblätter, Vol.* 20, *No.* 3, *p.* 210; *Monatsber. f. Chem.*, 16, *pp.* 674–683, 1895.)

The author has succeeded in determining the amount of iodine in solutions of potassium iodide, mercuric iodide, and lead iodide, by electrolysis, with considerable accuracy, by the use of a silver anode, weighed before and after the electrolysis. A sheet of platinum was used as a cathode; special care must be taken to notice whether the separation of the iodine from the solution is quite completed.

R. M. FRIESE—HOT-WIRE MIRROR INSTRUMENT.

(*Beiblätter, Vol.* 20, *No.* 3, *p.* 212; *Elektrotechnische Zeitschrift, Vol.* 16, *pp.* 726–727, 1895.)

The measuring instruments which can be used both for direct and alternating currents are (1) apparatus operating on the dynamometer principle, (2) the *electrometer*, and (3) hot-wire instruments. In using the dynamometer, a

resistance without self-induction and capacity must be introduced, so that the impedance of the apparatus itself can be neglected. For measuring small potential differences this is a disadvantage. The electrometer readily gives exact values for direct and alternating currents; but the use of this instrument generally presents difficulties to the practical man. The hot-wire instrument is, however, adapted for the measurement of direct and alternating currents, and is, moreover, entirely unaffected by external influences. The hot-wire instrument has a very low impedance, but is not very sensitive. The author has attempted to adapt the hot-wire instrument for use as an instrument of precision.

The hot-wire is located in and attached at the top to the upper end of a long tube mounted in and extending up over the cover of a box or chamber. The lower end of the hot-wire is attached to the upper side of one arm, l_1, of a lever, or balance beam, suspended from the cover of the box or chamber above mentioned. To the under side of the same arm, l_1, of the beam is attached a spiral spring, f_2, which keeps the hot-wire in tension, the lower end of this spring being secured to the bottom of the box. To the other arm, l_2, of the beam is secured a wire, connected to the bottom of the box through an Ayrton and Perry flat spiral spring, the tension of the said springs being so adjusted as to keep the balance beam in equilibrium; at the head of the Ayrton and Perry spring is mounted a mirror arranged to throw a beam of light on a scale in the ordinary way, an aperture being provided in the wall of the box for this purpose. To the head of the Ayrton and Perry spring is also attached a damping vane immersed in a bath of clean paraffin oil with which the bottom of the box is filled. When the hot-wire lengthens, the spiral spring f_2 draws down the arm l_1 of the beam, and consequently raises the arm l_2 of the beam; this motion increases the tension on the Ayrton and Perry spring, and thereby causes the head thereof to rotate. By the rotation of the head of the Ayrton and Perry spring, the mirror is turned and an elongation of the spot of light produced.

MAX WEIN—ON APPARATUS FOR VARYING THE SELF-INDUCTION OF A CIRCUIT.

(*Elektrotechnische Zeitschrift, Vol.* 17, *No.* 10, *p.* 154; *Wiedemann's Annalen, Vol.* 57, 1896, *p.* 249.)

The author has devised an apparatus for measuring the self-induction of a conductor; the principle of this apparatus is not new, but it enables the self-induction to be varied continuously from $4 . 10^5$ to $1{\cdot}2 . 10^8$ cm. in a very convenient manner.

The apparatus consists essentially in a fixed and a movable bobbin which are joined up in series with one another. The movable bobbin is capable of being turned through an angle of 180° about a vertical axis within the fixed coil, so that the directions of the currents in the two coils can form any desired angle with one another, and in the extreme cases can be arranged parallel or opposite to one another. The fixed coil is wound with many turns, of which any desired number

can be put into circuit by means of a series of terminals, the self-induction being increased by definite amounts in this way. For filling up these intervals the moving coil is employed, by the turning of which the self-induction of the whole can be varied continuously between smaller limits.

On the movable bobbin is provided a pointer which enables the angle through which the bobbin has been turned, to be read off on a horizontal graduated scale. The apparatus was calibrated by Maxwell's method with alternating currents and the Wheatstone's bridge, by being balanced against coils of known self-induction.

When it is to be used in the measurement of the self-induction of coils of wire, the coil to be tested, of self-induction p_1, is inserted into arm 1 of the Wheatstone's bridge combination $\left(\frac{12}{34}\right)$; in arm 2, the apparatus p_2; whilst arms 3 and 4 consist of a bridge-wire, which may have additional resistances on both sides if desired. In the bridge is a telephone receiver; the whole being supplied with an alternating current from a small Kohlrausch inductor. By varying the self-induction of the apparatus, and by adjusting the sliding contact, an approximation to silence can be obtained in the telephone. When this is so,

$$p_1 = p_2 \frac{\omega_3}{\omega_4}.$$

The apparatus can, moreover, be employed for measuring the capacity of condensers, with or without conduction, as well as the coefficient of induction of any conductor, as the case may be.

The balancing of a capacity with a self-induction is also effected by one of Maxwell's methods, with an alternating current and a telephone. The condenser, C_1, is arranged in arm 1 of the Wheatstone's bridge, in parallel with a resistance ω_1, the apparatus in arm 4; arms 2 and 3 are simple resistances. When there is no current in the bridge,

$$\omega_1 = \frac{\omega_2 \ \omega_3}{\omega_4};$$

and

$$C_1 = \frac{p_4}{\omega_2 \ \omega_3}.$$

As regards the measurement of the coefficients of induction of any conductor, of whatever kind it may be, according to the opinion of the author, any conductor behaves, with respect to a simple sine current, either (1) as a resistance with self-induction, or (2) as a resistance with a capacity in parallel therewith, or (3) as a resistance with a capacity in series therewith; that is to say, it can be replaced, as regards its action on a sine current, by a conductor of one of the three forms above mentioned. The equivalent magnitudes are then termed "effective" resistance, "effective" self-induction, and "effective" capacity. In cases 1 and 2, the "effective" magnitudes are measured as the "true" magnitudes. In case 3 the apparatus is introduced into arm 1 of the bridge behind the conductor to be tested—for smaller capacities, however—in parallel therewith.

ANON.—ELECTRICALLY-DRIVEN ROLLING MILLS.

(Elektrotechnische Zeitschrift, Vol. 17, *No.* 10, *p.* 162.)

Heretofore it has been considered an extremely difficult problem to drive a rolling mill by electricity. A successful installation of this kind has, however,

been at work for about two months in the brass rolling mills of C. Kulmiz, at Achenrain, in the Tyrol. This mill previously received its motive power from the Ache, but at times of continuous cold had to contend with scarcity of water, which frequently necessitated partial interruptions of work. To avoid this, 200 H.P. was taken from the Ache, at a point about 2·5 kilometres above the mills, by means of a turbine constructed by Messrs. Ganz & Co., of Budapest, Leobersdorf, and a part thereof transmitted to the works by means of a polyphase current. The generator in the turbine house is built for an output of 160 H.P. In the mills are two polyphase motors—system, Ganz & Co.—each of 60 H.P., which operate in conjunction with the turbines at the mills. The excess power of the turbines is used for lighting the mills and the town of Achenrain; and attention may be drawn to the fact that, in spite of the jars and sudden variations of load which occur in driving rolling mills, the light remains perfectly steady.

The installation has been tested up to its full capacity during a scarcity of water which occurred towards the end of January, when it dealt with the load easily; and, in fact, this installation has worked day and night without a hitch from the beginning. It may be mentioned that this is the first rolling mill in Austro-Hungary to be driven by a polyphase-current plant.

ANON.—ELECTRICAL LIFTING GEAR FOR LOCOMOTIVE WORKS.

(*Elektrotechnische Zeitschrift, Vol.* 17, *No.* 10, *p.* 162.)

Lately an electrically-driven travelling platform and two locomotive overhead travellers have been installed by the Machinen und Waggonfabrik of Simmering, near Vienna, for the Imperial Austrian Railway. The first of these arrangements is capable of dealing with loads of 60 tons, and is used for moving locomotives in the repairing shops at Knittelfeld; it runs on eight chilled wheels, which travel on four rails. In the bearings of the running wheels are suspended four transverse beams attached to a frame; on these transverse beams is mounted a track 8·1 metres long, at right angles thereto, and at the normal height of the rails in the shops, to receive the locomotive to be moved. At one side of this track the frame is extended far enough to carry a platform which is of the same length as the track, and where the driving gear as well as the electro-motor and a resistance box are mounted, and where also the attendant is stationed. The motor, which is mounted in the centre of the platform, actuates the driving gear through a friction clutch, which bears a worm-wheel, and which transmits motion through spur gearing to the running wheels, so that the loaded traveller is moved at a velocity of 15 metres per minute. For the purpose of bringing the locomotive on to the travelling platform, or removing it therefrom on to a fixed track, a second motion is employed which can also be put into gear with the motor by means of worm gear and the above-mentioned friction clutch. By means of this arrangement a wire hawser is wound on to a drum mounted beneath the frame of the travelling platform, the free end of this hawser being secured to the locomotive in a suitable manner, the locomotive being moved at a velocity of 10 metres per minute. In both cases the power required is about 8 H.P.; the current is supplied to the motor through two stretched cables arranged in the pit in which the platform moves, and on which run two spring contact rollers mounted

on the frame of the platform. Both in the driving gear for the longitudinal motion of the locomotive as well as in the gear for the transverse motion of the platform, is inserted a claw coupling between the worm-wheel and the spur gearing, and arrangements made for applying crank handles, so that at any time manual power can be substituted for the electric driving gear.

The somewhat more recently erected overhead travellers are each of 11·5 metres span, one being erected in the Knittelfeld, and the other in the Linz Works. On one side of the movable bridge, which consists of two steel-plate bearers stiffened by transverse and crossed ribs, is a platform where the switch-levers and a resistance box are mounted and the crane attendant is stationed. The electrical driving gear for moving the traveller along the track, which is 5·8 metres above the ground, is exactly similar to that employed in the travelling platform above described, and comprises worm gear and a friction clutch, and enables a velocity of 0·3 metre per minute to be attained. Each of the two elevators running on the main bearers is capable of lifting 22·5 tons, and can be moved to an extreme distance of 10·3 metres from its fellow; this motion being operated entirely by manual power by means of hand chains from below. The raising of the loads is, however, effected at a velocity of 0·5 metre per minute, by means of two electro-motors, one for each elevator, these motors being arranged similarly to those above described. Both in the travelling gear as well as in the elevating gear are provided claw couplings between the worm gear and the spur gearing; these couplings, when disengaged, enabling manual power to be employed, in which case eight men are required for raising or lowering a completely fitted locomotive.

CLASSIFIED LIST OF ARTICLES

RELATING TO

ELECTRICITY AND MAGNETISM

Appearing in some of the principal Technical Journals during the Months of MARCH and APRIL, 1896.

S. denotes a series of articles. I. denotes fully illustrated.

ELECTRIC LIGHTING AND TRANSMISSION OF POWER.

A. Rothert—Theory of Choking Coils and Transformers for Series Incandescent Lighting.—*E. T. Z.*, March, No. 10, p. 142 (I.).

Anon.—Concerning the Glow Lamp Commission.—*E. T. Z.*, March, No. 10, p. 148 (S.).

Max Meyer—The Hamburg Electricity Works.—*E. T. Z.*, March, No. 11, p. 168.

G. Pellissier—Utilisation of the Niagara Falls.—*Ecl. El.*, March, No. 10, p. 433, vol. 7, No. 17, p. 145, No. 15, p 54, No. 12, p. 549, No. 13, p. 577 (S. I.).

S. Hanappe—Experiments on Transmissions.—*Ecl. El.*, March, No. 11, p. 482, No. 12, p. 537 (S. I.).

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Anon —The Fabius-Henrion Electric Pump, with Water Regulator and Starting Gear.—*Ecl. El.*, vol. No. 17, p. 171 (I.).

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G. Rodmer—Notes on American Turbines.—*Ecl. El.*, vol. 7, No. 17, p. 160.

A. Crehore and G. O. Squier—Experiments with a New Polarised Photochronograph used for Measuring the Velocity of Projectiles.—*Ecl. El.*, vol. 7, No. 17, p. 173 (I.).

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A. L. Clark—A Method of Determining the Angle of Lag.—*Phil. Mag.*, vol. 41, No. 251, April, p. 369.

M. Loret—The Influence of Induced Currents on the Orientation of Live Bacteria. —*C. R.*, vol. 122, No. 16, p. 892.

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ANON.—The Aluminium Works of the Pittsburg Reduction Company at the Niagara Falls.—*E. T. Z.*, vol. 17, April, No. 15, p. 232.

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H. LUGGIN—Two further Researches on the Polarisation of Thin Metal Membranes. —*Wied. Ann.*, vol. 57. No. 4, p. 700.

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K. OCKS—On the Prospects of obtaining a Diaphragm which will prevent Diffusion without offering Resistance to the Current.—*Beibl.*, vol. 20, No. 4, p. 286.

CH. HENRY—Answer to Observations by M. Henri Becquerel relating to a Paper entitled, "On the Principle of an Accumulator of Light."—*C. R.*, vol. 122, No. 13.

HENRI BECQUEREL—Observations relating to the above Answer.—*C. R.*, vol. 122, No. 13, p. 791.

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2. The Library is open (except from the 14th August to the 16th September) daily between the hours of 11.0 a.m. and 8.0 p.m., except on Thursdays, and on Saturdays, when it closes at 2.0 p.m.

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JOURNAL

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Institution of Electrical Engineers.

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The Two Hundred and Ninetieth Ordinary General Meeting was held at the Institution of Civil Engineers, 25, Great George Street, Westminster, on Thursday evening, May 14th, 1896—Professor W. E. AYRTON, F.R.S., Past-President, in the Chair.

The minutes of the Ordinary General Meeting held on April 30th were read and approved.

The names of new candidates for election were announced and ordered to be suspended.

The following transfers were announced as having been approved by the Council :—

From the class of Students to that of Associates—

Esmond Morgan Abdel-Malek.	Albert H. Joyner.
Frank Armstrong.	Walter Herbert Russell.
Ernest Cardin.	Ernest Sherley-Price.
Leonard Johnston.	Charles Stirling.

Donations to the Library were announced as having been received since the last meeting from Mr. Perren Maycock and Mr. H. Doijer, to whom the thanks of the meeting were duly accorded.

Mr. J. L. Fuller, Associate, and Mr. W. P. Whitehead, Associate, were appointed scrutineers of the ballot for new members.

The following paper was then read :—

EXPERIMENTAL TESTS ON THE INFLUENCE OF THE SHAPE OF THE APPLIED POTENTIAL DIFFERENCE WAVE ON THE IRON LOSSES OF TRANSFORMERS.

By Stanley Beeton, C. Percy Taylor (Students), and James Mark Barr.

Introductory.

At the conclusion of some articles on "Wave-Form Synthesis," which were published in June, 1895,* we mentioned that we were then engaged in testing the iron losses in transformers with the aid of the method we had devised for easily altering the shape of the applied potential difference wave.

This question of iron losses has naturally been regarded as one of considerable importance by electrical engineers, since the success of every system of alternate-current supply depends to a great extent on the all-day efficiency of transformers. Hence we have thought that an account of some fairly complete experiments on this subject might be worthy of the consideration of this Institution. These experiments were carried out at the Central Technical College during May, June, and July, 1895.

Work of previous Investigators.

Up to August, 1895, when our investigations were completed, the most important contributions to the study of the effect of the shape of the alternating wave on the amount of iron loss in a transformer were the experimental tests of Dr. Fleming† and Mr. Steinmetz ;‡ while the theoretical side of the question had

* *The Electrician*, June 21st and 28th, 1895, vol. xxxv., pp. 257 and 286.

† *The Electrician*, June 28th, 1895, vol. xxxv., p. 304.

‡ *The Electrician*, August 24th, 1894, vol. xxxiii., p. 498.

been studied by Mr. Evershed* in 1891, and again more recently by Mr. Feldmann.†

Mr. Steinmetz carried out some tests in America in 1891, with a view to finding "whether there was any difference in the "action of transformers" when worked off alternators of the iron-clad and smooth-core types. An average difference of 9 per cent. in favour of the distorted iron-clad wave was observed; but it should be noticed that in these experiments the power lost in hysteresis was alone considered, whereas the total loss in the iron must decide the question as to which of the two machines it would be better to employ. To make Mr. Steinmetz's tests, then, of any real practical value, it becomes necessary to assume that the power wasted in eddy-currents does not vary with the form of the E.M.F. wave. And although we now think that this assumption is justifiable (as will be shown later), we do not consider that there was sufficient experimental evidence at that time to entitle Mr. Steinmetz to make this assumption. (It is possible that Mr. Steinmetz may have meant total iron loss when he spoke of hysteresis, but we cannot form any definite opinion on the point from the data given in his letter.)

Dr. Fleming, who found "differences of 10 per cent. and 15 "per cent. in the iron core losses," observed that "the iron core "loss in any transformer was greatest on that alternator the "E.M.F. curve of which most closely approximated to a sine "curve." For his tests Dr. Fleming employed several different types of alternators, and this necessarily limited the number of types of E.M.F. waves at his disposal. We think it was this limitation that led Dr. Fleming to the result stated above, for our tests certainly point to a conclusion which differs very materially from this.‡

In a series of articles on transformers in *The Electrician* in 1891, Mr. Evershed dealt pretty fully with the question of the

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* *The Electrician*, March 27th, 1891, vol. xxvi., p. 635.

† *The Electrician*, October 18th, 1895, vol. xxxv., p. 809.

‡ Since writing this we gather, from an article which appeared in *The Electrician* for January 10th, 1896, that Dr. Fleming has altered his opinion considerably.

applied P.D. waves and the corresponding iron losses in transformers, chiefly, though, from a theoretical standpoint. He sums up this part of his subject by saying: "The broad lesson "to be learnt from the diagrams is, that in studying iron losses "in the cores of the transformers we may neglect the slight "differences due to widely differing E.M.F. waves." Mr. Evershed has given, in vindication of this statement, three waves (viz., the sine, the rectangular, and the zigzag), which, though they differ considerably in *shape*, do not, for the same effective value, vary much in *area*. This, as we shall show later, is an essential point. It is not, therefore, very surprising that Mr. Evershed did not discover a large variation in the iron loss when considering these wave-shapes.

We come now to one of the most recent contributions to this question, namely, that of Mr. C. P. Feldmann. This consists of an entirely theoretical treatment of the subject of this paper.

One or two serious errors have been pointed out by Mr. Hay,* and by one of the authors† of the present communication, in Mr. Feldmann's reasoning. But quite apart from these mistakes we do not think that the principle and methods of this paper, in which unnecessary complications are introduced, could ever be made of great practical value.‡

Description of Apparatus.

Our transformer tests were carried out by obtaining the complete curves of potential difference and current by means of an electrometer and Joubert contact-maker. This method, while being simple and accurate, is absolutely complete; any results required can be calculated from the two curves taken. The P.D. was kept constant by means of an Ayrton and Mather

* *The Electrician*, October 25th, 1895, vol. xxxv., p. 857.

† *The Electrician*, November, 8th, 1895, vol. xxxvi., p. 61.

‡ The only complete account of an investigation on the subject of this paper —published, however, since August, 1895, when our investigations were completed—is that by Dr. Roessler. This is dealt with at the end of the communication.

electrostatic voltmeter; thus we used only electrostatic instruments which required no sort of correction, such as is necessary when wattmeters and dynamometers are employed.

The method we employed for varying the shape of the P.D. wave impressed on the transformer was, as already stated, the one described in *The Electrician* for June 28th, 1895. It consisted in throwing into the circuit, during similar parts of each half-wave, a resistance or capacity by means of an apparatus which we have called the "injector." It is indicated in the accompanying diagram (Fig. I., Plate 1), which also shows the details of the remainder of the apparatus used by us in testing the iron losses in the transformer.

The "Injector."—The arrangement which we have previously called the "injector," is shown diagrammatically at J. It consisted of two brushes, b_1 b_2, bearing on a commutator keyed to the shaft of the alternator. To these brushes was connected a resistance or capacity, as the case might be. We used a Ferranti alternator giving eight complete periods per revolution, and, in order that we could throw into the circuit any desired resistance or capacity during certain similar parts of *each half-wave*, the commutator was made with 16 segments. These segments—completely insulated from the machine and from one another—had no connections brought to them whatever; they were merely used to periodically short-circuit the two brushes b_1 b_2.

The position of the brush b_2 determined the *epoch*, or the instant at which the resistance or capacity was thrown into the circuit, while the distance between b_1 and b_2 determined the *interval*, or the duration of the effect for any given speed of the alternator.

To the other end of the alternator shaft was fixed the usual form of Joubert rotating contact-maker. The movable brush, C, and fixed graduated scale, used for taking the wave-forms, were also employed by us to fix the positions of the "injector" brushes in the following manner:—

Method of Setting the Injector Brushes.—The normal P.D. wave was first obtained in the ordinary manner, and by this means we really calibrated the fixed scale of the contact-maker; that is

to say, we found positions of the brush C corresponding with certain points in the wave of P.D., thus imparting a definite meaning to each point in the scale. Having decided over which part of the normal P.D. wave the injection was to take place, we found the points corresponding with this interval on the fixed scale of the contact-maker.

Let these points be a and d. The brush C was fixed with the pointer at a, and the alternator shaft turned until the metal web of the contact disc came under the brush (this is the position indicated in Fig. I.), and the trailing injector brush, b_2, was then adjusted till it was about to leave one of the segments. We next moved on the brush C to the point d, and turned the shaft of the dynamo until contact between the brush and the metal web was again restored. With the armature in this position the brush b_1 was set so that it was just coming on to the next segment behind the one which b_2 had been adjusted to leave. It is evident, therefore, that during the interval in which the armature moves from the position a to the position d, the resistance or capacity inserted between b_1 and b_2 would be in the circuit, and that during the remainder of the half-wave it would be short-circuited.

Transformer Details.—Our tests were carried out on a Mordey transformer designed for an output of 3 kilowatts. The transformer was wound with three coils, two consisting each of 12 turns, and intended to be used with a pressure of 50 volts, while the third, or fine-wire, coil was wound for a pressure of 2,000 volts. This latter and one of the former were left on open circuit throughout these experiments, and the other coil was used by us as the magnetising coil, taking about 3 amperes at a frequency of 100 ∿. Hence, as the resistance of this coil was only 0·016 ohm, the drop in pressure due to it was negligible.

Electrometer Connections.—The instrument used for taking our waves was an Ayrton and Mather quarter-cylinder reflecting electrometer, connected up in series with the Joubert contact-maker as shown in Fig. I. In parallel with the electrometer we had a small condenser, which was short-circuited by the key, K, after every reading.

A number of water cells (connected with the instrument as

shown in Fig. I.) were used to maintain a permanent P.D. between the opposite pairs of quarter-cylinders, and the P.D. to be measured was set up between the needle and the case. This method, as explained in our above-mentioned article, has the advantage of making the deflection directly proportional to the P.D. to be measured, even when the auxiliary P.D. required in the heterostatic use of an electrometer is quite small.

The only readings used in working out the tests were those taken with the electrometer; for this instrument was also employed to measure the P.D. between the ends of a non-inductive resistance, R, placed in series with the transformer, and so to indirectly measure the current flowing through the latter.

The electrometer was calibrated before—and in almost all cases after—every test with a set of 70 standard Clark cells.

In order to facilitate taking the instantaneous values of both P.D. and current in quick succession, two change-over switches were used at A and B.

A consisted of a solid block of paraffin wax, in which were cut two long slots and two rows of small holes, all of which were filled with mercury.

The electrometer and contact-maker were directly connected with the two slots, while to the small holes were led wires from the terminals of the transformer and the non-inductive resistance R, or from any points in the circuit between which we wished to find the instantaneous value of P.D. As a matter of fact, the terminals of the "injector" were also connected with a pair of holes in the change-over switch A; but these wires are not shown in the diagram, as the graph obtainable at these points was not always taken, and it did not form an essential part of the transformer test.

The value of the non-inductive resistance was 4·15 ohms, so that the maximum reading for obtaining the current-wave was about 16 volts, whereas the maximum ordinate of some of our P.D. curves was as high as 100 volts. In order, therefore, to use the full range of the electrometer in each case, it was necessary to change the potential to which the quarter-cylinders were charged; hence for the P.D. wave we used six cells between the

opposite pairs of quarter-cylinders, and for the current-wave 30 cells, the middle of either set being connected with the case as indicated in Fig. I. This alteration was effected by means of the change-over switch B.

An Ayrton and Mather electrostatic voltmeter, V, was used to keep the R.M.S. volts at the terminals of the transformer constant during each test.

Speed of the Alternator.—The speed of the alternator, which could be adjusted by means of coned pulleys, was kept constant at 750 revolutions per minute, thus giving a frequency of 100 ∿. No electrometer reading was taken unless the speed, as shown by a Rungs pneumatic speed indicator, was exactly right. The indicator was checked several times by a revolution counter, and found perfectly accurate.

Advantages of Open Secondary Tests.—Since it is now generally admitted that, with the exception of a slight drop due to leakage at high loads, the total iron losses in a transformer are constant at all loads for the same frequency, we made all our tests with open secondary circuit.

This method of attacking the subject offers great advantages, because errors caused by the variations of temperature in the iron core and the non-inductive resistance R, due to the use of different currents, are not introduced into our experiments. In addition to this, it will be seen that the working out of our results is somewhat simplified, especially with respect to the determination of the maximum induction. It is in the determination of the iron loss, however, that the method possesses its chief advantages, for we can measure this loss directly, and not as the difference of two much larger quantities. By this means we have been able to find the iron loss accurately to within $\frac{1}{2}$ per cent., which would have been quite impossible with a load on the secondary.

Discussion of Curves.

All the curves of P.D. and current given in the figures have been obtained by taking the means of the homologous readings on each half-wave. The mean wave thus determined was never

found to differ appreciably in any way from the positive or negative half-wave. Each wave was drawn as the observations were made, so that, when the exact contour of the wave appeared doubtful, more readings at points intermediate between those already observed could be *at once* taken and plotted; hence a large number of observations were made on every wave, sometimes as many as 48 points being taken.

The normal P.D. wave of the Ferranti alternator (Fig. IV. E, Plate 3) is seen to be very nearly a sine curve, while the current-wave possesses the characteristic deformation always observed when a transformer is working light.

Induction Waves.—The induction wave must be found by integrating the curve of back E.M.F. Now in our case the latter is practically identical with the applied P.D. wave, since the drop in pressure due to the resistance of the magnetising coil is negligible.

It is interesting to note how smooth the outlines of the induction curves are, even when derived from very distorted waves of potential difference. This point has been fully dealt with by Mr. Evershed in the articles referred to above.

We have, therefore, to integrate the P.D. wave; but to do this, we require some starting point, and this must first be found. When the ordinate which divides the half-wave of P.D. into two parts of equal area is known, this presents no difficulty, as the induction must be zero at the point where this ordinate cuts the axis of time. When, however, as is more often the case, we do not know this ordinate, then the above relation will not help us; but there is another relation which is true in every case, viz., *that the induction must be a maximum when the P.D. is zero.*

It is evident, on reference to Fig. 2, that, according to this relation, the induction must pass from a negative to a positive maximum, or *vice versâ*, during the half-period of the P.D. wave. Since the induction wave is the integral of the P.D. curve, it will also be evident from Fig. 2 that *the area of the semi-wave of P.D.*, multiplied by the required constant, will give twice the maximum induction. (This constant must contain the number

of turns in the magnetising coil and the cross section of the iron core.) Thus in every case we can get a starting point for the induction curve by setting up the maximum induction at the point where the P.D. is zero.

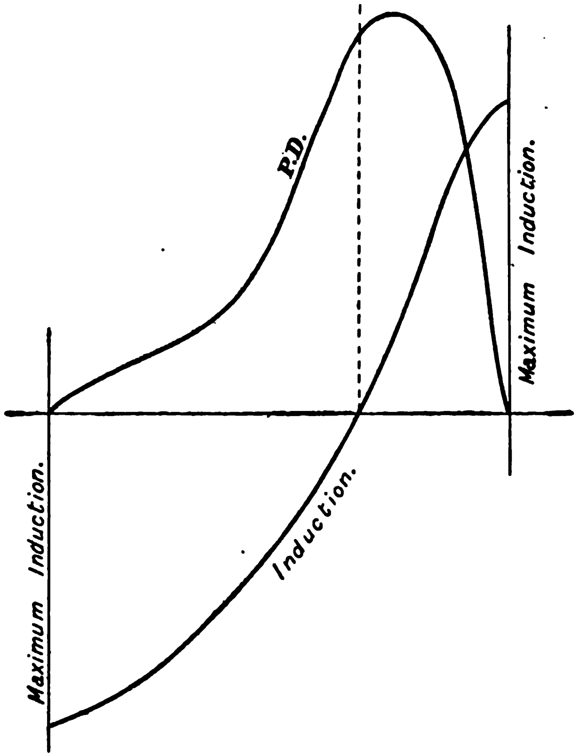

Fig. 2, showing the Relation between the P.D. and Induction Curves in a Transformer.

The wave is then drawn by integrating the P.D. curve in steps from this point, and subtracting the inductions thus obtained from the maximum value.

This direct relation between the maximum induction and the area of the P.D. wave is of the greatest importance, for it is evident then that the *amount of hysteresis loss* for different shapes of applied P.D. waves will depend only on the *areas of these waves.*

Power Curve.—The actual mean power supplied to the

transformer was determined by finding the products of corresponding instantaneous values of the applied P.D. and current. The products thus found were plotted as curves (see Figs. III. and IV., Plates 2 and 3), which were then integrated with a planimeter, and the mean ordinate determined. This then gave us the input, and, since the copper loss was negligible—being less than one-fifth of a watt—it represented with sufficiect accuracy for our purpose the total watts lost in the iron core of the transformer.

EFFECTS OF THE INJECTOR.

As this paper is essentially one dealing with transformer tests, we do not propose to discuss at any length the effects obtained by the use of the injector, but it may be useful to consider one typical case of injected resistance and one of capacity. The effect of injecting rather a large resistance when the current is *not in phase* with the P.D. maintained between the terminals of the transformer is well illustrated by the wave shown in Fig. III. A, Plate 2.

In this test, a resistance of 36 ohms was thrown in over the first part of the wave; but, in addition, we had a capacity of 96 microfarads *permanently* in the main circuit, which brought the current

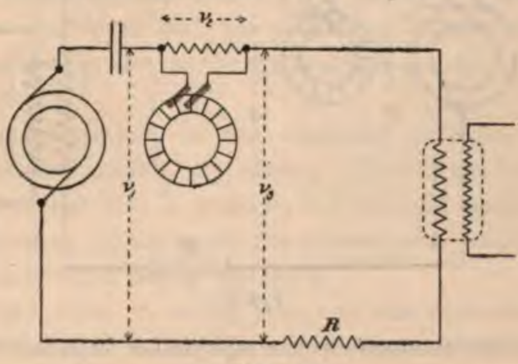

FIG. 5.

into phase with the P.D. between the terminals of the alternator. By bringing the current into phase with the P.D. we mean that the zero readings of the two waves occurred at the same point, but the waves, of course, possessed very different shapes.

The distinguishing feature of this wave is the curious sort of hump which occurs just at the beginning. The explanation of this is not hard to find. It will be observed that during the interval in which the current is opposite in sign to the P.D. the ordinates of the latter curve tend to increase, but directly the current-wave crosses the zero line the P.D. begins to decrease.

Consider for a moment the instantaneous P.D.'s between the terminals (1) of the machine and condenser, (2) of the injector, (3) of the transformer and resistance R, represented by v_1, v_2, v_3 (Fig. 5) respectively, during the interval just alluded to.

Since the current is in the opposite direction to the terminal P.D. of the transformer, we have:

$$v_1 = v_3 - v_2;$$
$$v_3 = v_1 + v_2;$$

that is to say, for this short interval the P.D. across the transformer equals the sum of the P.D.'s of the machine and the injector. This, then, fully accounts for the presence of the *hump*.

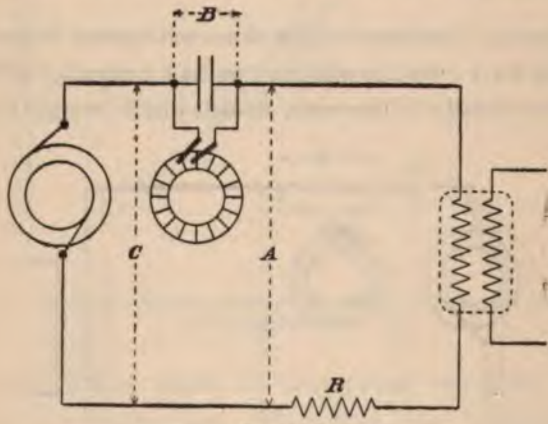

Fig. 6.

The effects obtained by the injection of capacity will be best explained by a reference to Fig. 6, and Fig. VII. (Plate 4). In the latter we have shown (Curve A) a P.D. wave at the terminals of the transformer and non-inductive resistance R (Fig. 6). This was obtained by adding, at each point, the drop in pressure due to this resistance to a curve obtained at the terminals of

the transformer, and shown in Fig. IV. G (Plate 3). The interval during which the condenser (60 microfarads) was in circuit is also shown in Fig. VII., and the curve of P.D. between its terminals (*i.e.*, the brushes b_1, b_2, Fig. I.), marked B, was obtained by integrating the current-wave during this interval.

By combining these two waves we get the P.D. between the terminals of the alternator, shown in Curve C. Since the condenser P.D. is obtained by integration, its maximum necessarily occurs when the current crosses the zero line. This maximum value is directly proportional to the area of the current-curve from the point of injection to its zero point, and inversely proportional to the capacity of the condensers injected.

On referring to Fig. VII., we note that, since the current is large when the condenser is thrown into circuit, the curve B rises very rapidly, and therefore the curve A turns down very rapidly away from Curve C, and crosses the zero line where B and C cross each other. The maximum point of the condenser P.D. curve of course occurs at the same time as the maximum *difference* between Curves A and C, and thus, when the curve B turns down, A bends over and begins to approach C, which it crosses when B crosses the zero line. Soon after this the condenser is short-circuited, and thus B follows the zero line and A is again coincident with the alternator P.D. curve, C. This coincidence lasts as long as the condenser is cut out of circuit by the "injector."

The points marked on the condenser potential difference curve, B, were obtained by experiment. They do not lie accurately on the curve, but this is probably due to slight sparking at the injector brushes, which made the electrometer readings somewhat unsteady when taking this wave.

Our chief object in taking points on this curve was to set at rest any fears that might have been entertained as to the advisability of periodically throwing in and removing from a circuit a bank of condensers. It has been shown that when a circuit possessing capacity in the form of condensers is br
there may be a sudden rise of potential at the terminals
latter. No such rise of P.D. was observed in our exp

and this was due to the fact that the condenser circuit was *never really broken*, for the capacity was removed from the circuit by being short-circuited.

Discussion of Results.

Our great aim at the time of carrying out these experiments was to find some definite *law* connecting the iron loss in the transformer with the shape of the applied P.D. wave. In no work published on the subject at that time could we find any results or conclusions which could form the basis of a connected theory regarding this question. None of the investigations on this subject had justified any conclusion which could materially help in judging of the exact, or even relative, value of wave-forms not actually tried.

The conclusions that we came to were—

1. *That if the R.M.S. value of the applied P.D. is constant, and the area of the P.D. wave is constant, then, whatever be the shape of this wave, the total iron loss cannot vary.*
2. *That if the R.M.S. value of the applied P.D. is constant, but the area of the P.D. wave varies, then, whatever be the shape of this wave, the total iron loss will vary by an amount which is only dependent upon the area of the P.D. wave.*

We feel fully justified in coming to these conclusions, for, as we have shown above, the hysteresis loss depends only on the area of the P.D. wave, and *we have proved experimentally that the eddy-current loss is constant for a given effective P.D.* This we refer to again below.

The results calculated from our tests will be found in as concise a form as possible in Table I.

Hysteresis Tests.—In order to get a complete theory regarding the iron losses, it was essential that we should separate those due to hysteresis and to eddy-currents. To determine the former loss, then, hysteresis tests were made on the transformer itself by a method independently suggested and used by Professor Ewing*

* Paper on Magnetic Qualities of Iron, Royal Society, April, 1894.

and Dr. Hopkinson. We found this method most satisfactory.

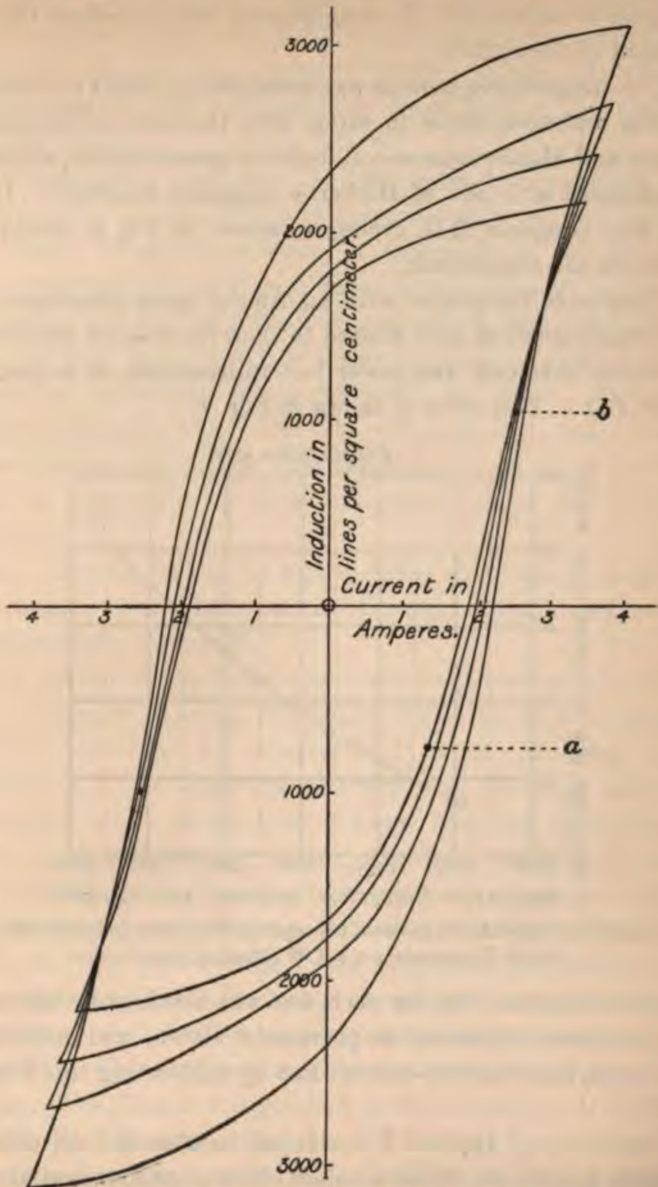

Fig. 8.—B.H. Cycles for a 3-K.W. Mordey Transformer.

The two 12-turn coils of the transformer were used, one

magnetising and the other as the test coil. A large resistance was put in series with the magnetising coil to reduce the time constant of the circuit.

The magnetising current was measured by means of a standard Weston ammeter, while in series with the test coil we had an Ayrton and Mather narrow-coil ballistic galvanometer, which was standardised with one of Hibbert's magnetic standards. In this way four complete B.H. cycles, as shown in Fig. 8, were determined for the transformer.

They were integrated with an Amsler polar planimeter, and the results obtained were plotted to show the relation between the maximum induction and power lost in hysteresis, at a frequency of 100 ∿. This curve is shown in Fig. 9.

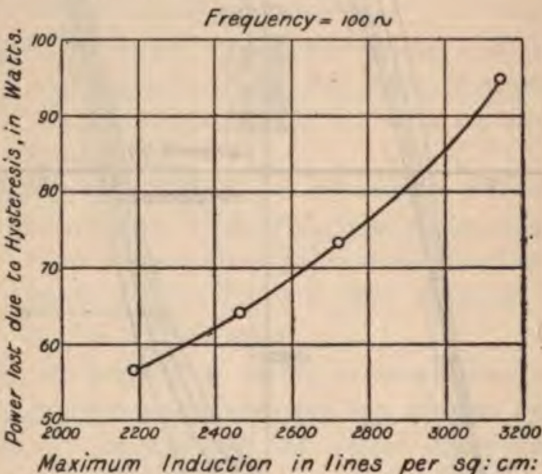

Fig. 9.—Curve showing the Relation between the Maximum Induction and Power lost in Hysteresis in a 3-K.W. Mordey Transformer.

The hysteresis loss for each test was obtained by calculating the maximum induction as previously shown, and referring to this curve, and the eddy-current loss by subtracting this from the total.

Variation of Applied P.D.—It will be observed, on reference to Table I., that the effective values of the applied potential difference are not all the same: they vary between 48 and 50 volts. This is due to the fact that they are not instrument readings, but

are calculated from the curves by means of the first moment planimeter. The method of using this instrument to give the R.M.S. value of a curve was described in the articles referred to elsewhere.* It was due originally to Mr. Turner, one of the demonstrators in the mathematical department of the Central Technical College.

We have given preference to this method of obtaining the effective values of both P.D. and current mainly for two reasons, viz.: Firstly, far greater accuracy is attainable by this method. This is easily understood when it is remembered that, by increasing the number of water cells used in conjunction with the electrometer, this instrument could be made as sensitive as we wanted, whereas the sensibility of the voltmeter was fixed. Secondly, by calculating *all* results from the curves of P.D. and current, any small errors which arise from inaccurate readings or drawing appear in them all, and these are made of far less relative importance.

The voltmeter V (Fig. I.) was therefore only used to keep the effective value of the P.D. constant throughout each test, and it was not specially calibrated.

This method of calculating the results has, however, introduced some difficulty in drawing conclusions from our experiments, as the small variations in effective P.D. must be taken into consideration. The difficulty of arriving at the true effect of this variation arises mainly from the fact that the eddy-current loss has been obtained by taking the difference of two much larger quantities, and thus the probable error is a large percentage of the whole range of variation. After a careful study of columns 2 and 7 of Table I., we came to the conclusion that, within the limits of accuracy attainable by our experiments—*i.e.*, about ½ per cent.—the eddy-current loss is proportional to the square of the applied P.D. This leads at once to the further conclusion that *the eddy-current loss is independent of the wave-form of P.D. so long as its R.M.S. value is constant.*

In order that this variation of applied P.D. should not obscure the true meaning of our results, we have calculated the change

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* *Electrician*, July, 1895, vol. xxxv., p. 290.

in the iron losses produced by the difference in the value of the applied P.D. from 50 volts, and thus found the iron losses for each wave-shape corresponding to an applied P.D. of 50 volts. The methods of correction employed were as follows:—

The effect of variations in the R.M.S. value of the P.D. is most marked in the case of the eddy-current loss, so that we will deal with this first.

We have, then, here corrected the eddy-current loss to a value corresponding to a common effective applied P.D. of 50 volts. In doing this, since each test is corrected separately, we only assume that, *so long as the wave-shape of P.D. is constant*, the eddy-current loss varies as the square of the effective volts.

Table I.

RESULTS OF TRANSFORMER TESTS CALCULATED FROM CURVES.

Figure.	R.M.S. or Effective Values.		Apparent Power in Watts.	Iron Losses in Watts.			Power-Factor.	Maximum Induction in Lines per Sq. Cm.
	P.D. in Volts.	Current in Amperes.		Total.	Hysteresis.	Eddy-Currents.		
3 A	49·5	2·42	120·0	92·5	60·5	32·0	0·77	2,330
3 B	49·8	2·75	137·0	95·5	63·0	32·5	0·70	2,410
3 C	48·5	2·81	136·0	93·5	65·0	28·5	0·69	2,490
3 D	48·9	2·95	144·5	97·5	66·0	31·5	0·67	2,520
4 E	49·2	3·03	149·0	103·0	71·0	32·0	0·69	2,680
4 F	48·1	2·92	140·5	104·5	74·0	30·5	0·75	2,750
4 G	49·5	2·80	138·5	111·0	76·5	34·5	0·80	2,800
4 H	48·1	2·85	137·0	106·0	76·0	30·0	0·77	2,790

From Table II. we see that, with the exception of the tests shown in Fig. III. C (Plate 2) and Fig. IV. G (Plate 3), the eddy-current loss is practically constant; the variation of half a watt meaning only ½ per cent. in the determination of the total loss.

Again, for the correction of the hysteresis loss we need only consider laws which hold so long as the wave-form is constant. Under these circumstances the area of the P.D. wave varies directly as the R.M.S. value. Now the area gives us at once the maximum induction, and the corrected hysteresis loss is then got by a further reference to Fig. 9. The values thus obtained are *given in column* 4 of Table II. The corrected total loss is now

Table II.

RESULTS OF TESTS CORRECTED FOR A COMMON EFFECTIVE P.D. OF 50 VOLTS.

FIGURE.	R.M.S. or Effective P.D. in Volts.	Maximum Induction in Lines per Sq. Cm.	Iron Losses in Watts.		
			Hysteresis.	Eddy-Currents.	Total.
3 A	50	2,350	61·0	32·5	93·5
3 B	50	2,420	63·0	32·5	95·5
3 C	50	2,560	67·0	30·0	97·0
3 D	50	2,570	67·5	33·0	100·5
4 E	50	2,720	73·0	33·0	106·0
4 F	50	2,850	79·0	33·0	112·0
4 G	50	2,830	78·0	35·0	113·0
4 H	50	2,900	82·0	32·5	114·5

determined by the addition of the eddy-current and hysteresis losses, from which we obtain the curve given in Fig. 10.

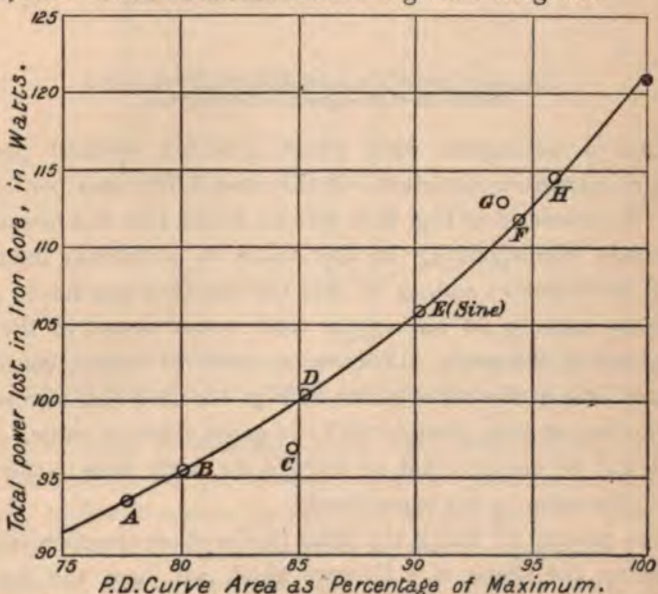

FIG. 10.—Curve showing Relation between the Total Power lost in the Iron Core of a Transformer, and the Area of the Applied Potential Difference Wave expressed as a Percentage of the Maximum Area possible with a R.M.S. value of 50 Volts.

The letters A to H refer to the curves given in Figs. III. and IV.

The Relation of the Iron Losses to the Area of the P.D. Wave.—In Fig. 10 we have shown the relation between the total power lost in the transformer and the area of the P.D. wave expressed as a percentage of the maximum area possible with the given R.M.S. value of 50 volts.*

This maximum area occurs with the rectangular shape shown in Fig. 11.

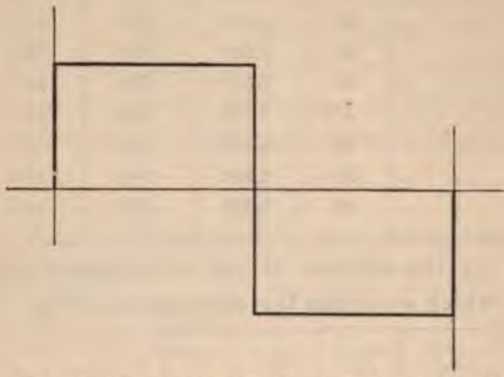

Fig. 11.—Type of the Least Efficient Wave of P.D. Maximum value equal to effective value.

Such a rectangular wave would give the greatest possible value of maximum induction—in this case 3,020 lines per square cm. On reference to Fig. 9, it will be found that the loss due to hysteresis corresponding to this value of maximum induction would be 88 watts; adding to this the constant loss due to eddy-currents—namely, 33 watts—the total power wasted in the iron comes out at 121 watts. This value must, of course, constitute the top limit of the curve shown in Fig. 10, since this wave-shape has the largest area possible with the given effective value.

It will be noticed that we have gone fairly close to the limit in this direction in our experiments.

The process of fixing the limit in the other direction consists of finding the shape of P.D. wave which will have the *smallest* area for the given effective value.

* It may be of interest to point out here that the ratio of the area of the P.D. wave to its maximum possible value is the reciprocal of the ratio more recently called by Dr. Fleming the "form-factor."

Now it will be obvious that before the area of a wave of constant R.M.S. value can be very much diminished *the maximum ordinate must of necessity be increased.* We cannot, therefore, diminish to any great extent the hysteresis loss without necessitating higher insulation.

If, on account of this difficulty, the maximum ordinate of the P.D. wave must have a definite limit (*e.g.*, maximum value not to exceed twice the effective value), the shape giving the least iron loss will be that shown in Fig. 12.

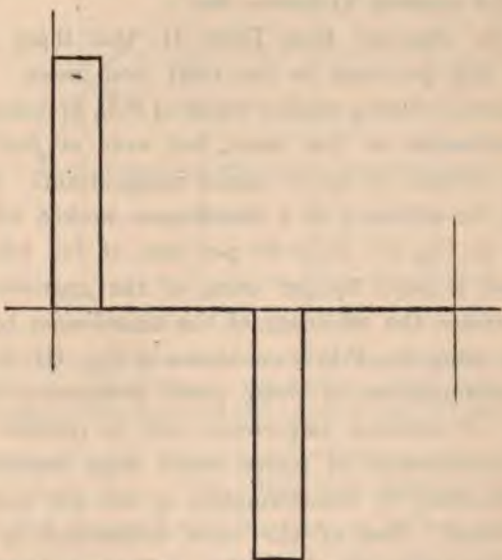

Fig. 12.—Type of the Most Efficient Wave of P.D., when maximum value equals twice effective value. (Same scale and effective value as in Fig. 11.)

This is again rectangular, which may seem curious, but the essential point is to get as wide a peak as possible, and thus, as it were, confine the wave to one part of the period. This wave has been drawn to the same scale as the one given in Fig. 11. The area of the curve shown in Fig. 12 will be found to be exactly 50 per cent. of the possible maximum (Fig. 11); in fact, with waves of this type having a constant R.M.S. value, the area (and, therefore, the maximum induction) is inversely proportional to the maximum ordinate.

This gives us a measure of the minimum possible hysteresis loss with different allowable P.D. maxima.

It is evident that, *unless* the maximum ordinate of the wave is limited, its area can be infinitely reduced while its R.M.S. value remains constant.

Advantages of Peaked Waves of P.D.—Our lowest iron loss is that given by the P.D. curve shown in Fig. III. A (Plate 2). This is due to the fact that it approaches most closely to the form shown in Fig. 12, thus giving the least area, and, consequently, the smallest hysteresis loss.

It will be observed from Table II. that there is a total variation of 22½ per cent. in the total iron losses. The consequent economy of using peaked waves of P.D. of course becomes especially noticeable at low loads, but even at *full* load the saving thus effected is by no means insignificant. For let us assume that the efficiency of a transformer worked off the P.D. wave shown in Fig. IV. H, is 95 per cent. at full load, then, if the iron loss is (say) 2½ per cent. of the maximum output, we would increase the efficiency of the transformer to over 95½ per cent. by using the P.D. wave shown in Fig. III. A (Plate 2).

Under circumstances of cheap power production this saving may not be of extreme importance, but in systems of distribution or transmission of power where large transformers are used, the efficiency of transformation is not the only question to be considered. One of the chief difficulties in designing large transformers is the providing of adequate means for keeping them cool, and any means by which the necessity for special cooling arrangements can be materially reduced will be sure to commend itself to those who have to deal with large transformers.

No-Load Current.

We have not been able to arrive at any satisfactory explanation of the variation of the no-load current with the shape of the applied P.D. wave. The curve given in Fig. 13, however, is interesting as showing that the maximum current occurs with the sine wave of P.D. The power-factor for this wave (IV. E, *Plate 3)* is also the smallest (Table I.).

This is a distinct point against the use of sine waves of P.D. with transformers, especially in cases where many transformers have to be kept magnetised on light secondary load at the end of long mains; in cases such as these the mains losses—which

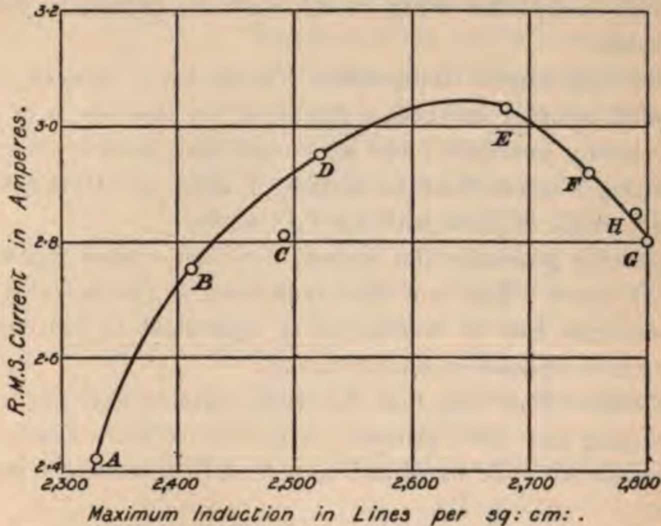

Fig. 13.—Curve showing Relation between Maximum Induction and R.M.S. Current in a 3-K.W. Mordey Transformer. (From Table I.) The letters A to H refer to the curve given in Figs. III. and IV.

vary as the square of the current—form a very appreciable item of the whole loss. The difference between the R.M.S. currents in cases A and E, for instance, is 25 per cent., so that the mains losses in case E would be more than 50 per cent. greater than in A.

In order to arrive at a satisfactory explanation of the shapes of the current-waves, they must be considered as built up of two components—a hysteresis component and an eddy-current component.

We have split them up in this way in Fig. III., Plate 2, and Fig. IV., Plate 3; the hysteresis component was obtained from the induction curve by means of the B.H. curves in Fig. 8, and the eddy-current by taking the difference between this and the total current curve.

It will be at once apparent that the peculiarities of the

current-curves are due almost entirely to the eddy-current component; the hysteresis parts are all very similar in shape.

The roundness of the curves, especially noticeable in Fig. III., Curves B, C, and D, is entirely due to the eddy-currents; the hysteresis component being in all cases comparatively flat on both sides.

The eddy-current components having been obtained by a somewhat complex method, a discussion on the details of each one is hardly justifiable; but as a class they exhibit some very interesting features, the most notable of which is that the curves are very nearly in phase with the P.D. waves.

Speaking generally, the curves also have shapes similar to the P.D. waves. This is a clear indication of the fact that the eddy-currents may be considered as equivalent to one current flowing in a supposed secondary circuit.

It follows from this that the eddy-currents have the effect of bringing the total primary current curve more nearly into phase with the P.D. wave, and thus tend to increase the power-factor.

It will be noticed that in all the curves, with the exception of IV. E, Plate 3, the eddy-current component leads slightly in front of the P.D. wave; it is, however, so slight that it needs some corroboration from other experiments. The only explanation possible seems to be that the plates of the core, being separated by insulating paper, form a condenser, thus causing a small capacity current as well as the ordinary eddy-currents.

Notes on Investigation by Dr. Roessler.*

The conclusions at which we arrived in August were partly anticipated, we found, by Dr. Roessler in a paper read in Germany in July, 1895, but not published in England until November. Dr. Roessler, however, since he could only experiment with two wave-forms of applied P.D., could not prove by experiments the results which he obtained theoretically.

We gather from an article in *The Electrician* on January 10th,

* See *The Electrician*, November and December, 1895, vol. xxxvi., pp. 124–222.

1896, that Dr. Fleming did not at that time consider it *proved* that the hysteresis loss in a transformer depended only on the form-factor of the applied P.D. wave,—or on its area, which comes to the same thing.

Dr. Roessler's system of measurement differs very materially from ours. To obtain the power given to the transformer Dr. Roessler employed the usual form of dynamometer-wattmeter, with its necessary corrections, and this gave rise to some rather complex calculations with the different currents.

Dr. Roessler treats the question very largely from a mathematical standpoint, and introduces a correcting factor into his formulæ for each typical wave-shape; but he does not appear to have fully appreciated the fact that the whole question of hysteresis loss is wrapt up in the *area of the applied P.D. wave*, independently of the R.M.S. value.

In this paper we have shown that it is this *area* alone which determines the hysteresis loss of a transformer.

Dr. Roessler makes some interesting comments on the equation,

$$E\,p_1 = J_1\,\omega_1 + 0{\cdot}4\,\pi\,\frac{n_1^2}{l}\,S\,\frac{d\,B}{d\,H}\,\frac{d\,J_1}{d\,t}\,\text{*},$$

in which $E\ p_1$ = primary P.D., J_1 = primary current (both *instantaneous* values), n_1 = primary turns, and l and S are respectively the length and cross section of the path of the lines in the iron.

The following sentence occurs:—"If . . . the alternator gives "a very pointed potential curve, and very high maximum value, "the maximum value of $\frac{d\,B}{d\,H}\,\frac{d\,J_1}{d\,t}$ must be very great. *But* $\frac{d\,B}{d\,H}$ "*is independent of the alternate-current curve*" [the italics are ours], "and only depends on the hysteresis curve; hence the value "of $\frac{d\,J_1}{d\,t}$, which is simultaneous with the maximum value of the "potential curve, must be greater with pointed curves than with "flat."

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* *Electrician*, November 29th, 1895, vol. lxxxvi., p. 153.

This is not necessarily so, and the reason is this—that the value of $\frac{d\,\mathrm{B}}{d\,\mathrm{H}}$ *is* dependent on the form of the P.D. curve in so much as it is dependent on the point on the hysteresis cycle at which we are working, and this, again, on the part of the period at which the maximum value of P.D. occurs.

Compare Figs. III. A and III. B.

In A, when the P.D. is at its maximum, the induction curve has not crossed the zero line, and we are working at the point marked "a," Fig. 8; but when the P.D. is a maximum in B we are working at the point "b," Fig. 8: the value of $\frac{d\,\mathrm{B}}{d\,\mathrm{H}}$ at b is 70 per cent. greater than at a, and this is why the current-curve is so steep at the time of maximum P.D. in A and comparatively flat in B, although the maximum P.D.'s in these two only differ by 10 per cent.

The steepness of the curve in A is also partly due to the eddy-currents; the reason for this is indicated on p. .

In conclusion, we wish to thank both Professor Ayrton and Mr. Mather for their kindness and help throughout these experiments; and we are especially grateful to Professor Ayrton for the assistance he has rendered us in the preparation of this paper.

APPENDIX.

Before deciding on the method described in this paper for obtaining potential difference waves of any desired shapes, we considered the practicability of using a series of alternators coupled on one shaft. By this means various component harmonics differing in phase, amplitude, and frequency could be produced and combined to give any desired wave-shape.

This idea of combining harmonics to obtain prescribed results has been known for some time. Lord Kelvin used it in his famous tide-predictor, and it was afterwards employed by Professors Ayrton and Perry in 1877 in their apparatus described in a paper on "The Music of Colour and Visible Motion."*

* *Physical Society*, November 23rd, 1878.

Although this method would have been in some ways very convenient, we were obliged to dismiss it as too expensive. It is also difficult to get waves of very great irregularity by this method. Dr. Fleming, in reference to this method,* remarked that three such alternators, giving frequencies in the ratio 1, 3, 5, would be sufficient for the majority of curves met with in practice. We were anxious, however, to experiment with waves *not* actually met with in practice, since our aim was not so much to find out which alternator now on the market was the best, but rather to give some information, if possible, which

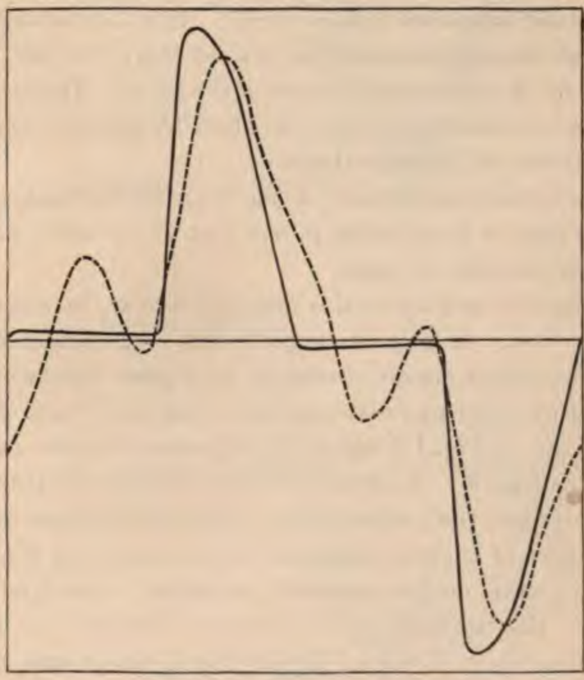


Fig. 14.—The Continuous Line Curve shows Wave actually produced with Injector. The Dotted Line Curve shows Wave that would be produced by combining the First Three Odd Harmonics.

might be a guide in the future design of alternators for use on transformers.

* *Electrician*, June, 1895, vol. xxxv., p. 304.

On considering the question more fully, we also find that the first three odd harmonics given by the series of alternators just mentioned would not, in many cases of not very distorted waves, give a close approximation to the true shape; thus, we find that, in order to get a peak in one part of a wave, it is necessary to cause the rest of the period to consist of a series of irregular undulations. We cannot, in fact, by this method alter one part of the wave without getting into difficulties with the rest of it.

This point is brought out very clearly in Fig. 14. Here we show a wave which we have produced by our method of "injection,"* and also the wave given by the combination of its first three odd harmonics (dotted curve). It will be noticed that, though this wave approaches the desired shape at the peaked part, it is far from it during the rest of the period. The harmonics for this wave were obtained with one of Coradi's harmonic analysers, by the courtesy of Professor Henrici.

It is here that our method has one of its chief advantages. If we want a peak or a depression in one part of our wave, we make it, and leave the rest in peace.

The injector method is also one which may be adopted at very little cost. It may be argued that the condensers are expensive, but they are not *necessary*, as a great variety of waves can be got by injecting resistance, and using more than one pair of brushes (b_1, b_2, Fig. I.), and so getting more than one injection on each half-wave. It should also be remembered that, when using condensers, the greatest effect is got with the least capacity.

The effect of higher harmonics on the area of a P.D. wave (and consequently on the maximum induction) cannot be stated generally. But it may be of interest to indicate the general principles on which it rests. To do this a simple case may be taken as an example. It is only necessary to consider odd harmonics, as even ones make the waves unsymmetrical about the time line.

Consider the case of a third harmonic superimposed on a

* This wave, and the method of obtaining it, was given in *The Electrician*, June, 1895, vol. xxxv., p. 289.

fundamental sine wave as shown in Fig. 15. The amplitude of the harmonic is here three-tenths of that of the fundamental.*

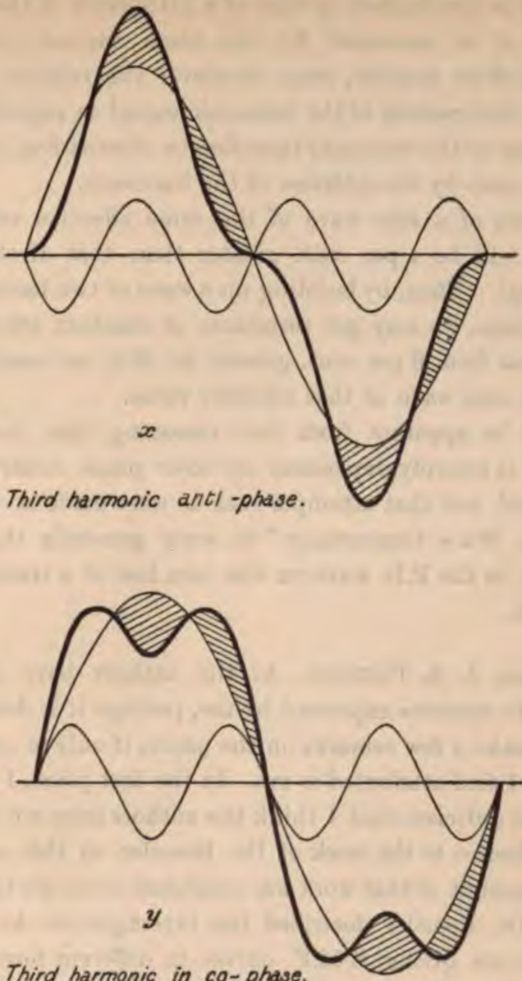


FIG. 15.

The two extreme cases are shown, namely, those with the harmonic in co- and anti-phase. The effective value of the

* Unless the ratio of the maximum of the fundamental to the maximum of the harmonic is greater than the ratio of their wave-lengths, the curve will dip below the zero line at the ends of the half-period, in cases such as shown in x, Fig. 15.

resultant is the same in each case (viz., very nearly 4 per cent. greater than that of the fundamental), but in x the area of the semi-wave is *diminished* by that of a half-period of the harmonic, and in z it is *increased* by the same amount; this is the maximum effect possible, since, whatever the relative phases be, two of the half-periods of the harmonic cancel as regards area.

The area of the wave may therefore be *diminished or increased* by 10 per cent. by the addition of the harmonic.

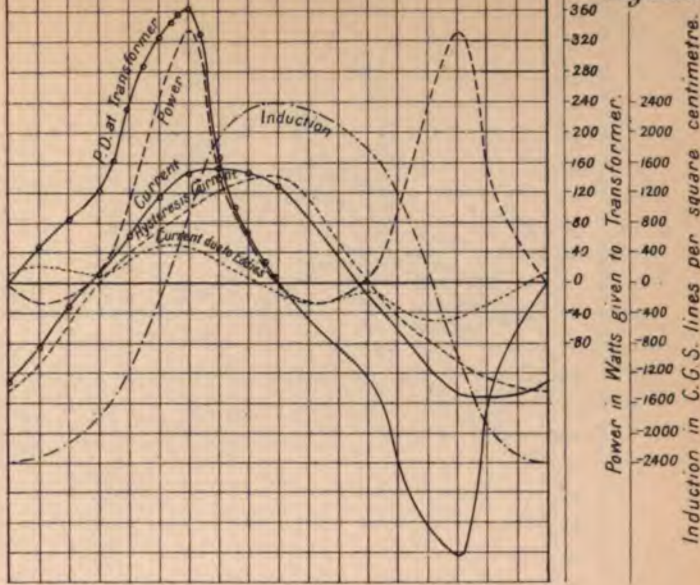
The area of a sine wave of the same effective value as the resultants will be 4 per cent. greater than that of the original fundamental. Thus, by building up a wave of two harmonics such as here chosen, we may get resultants of constant effective value having areas from 6 per cent. greater to 13·5 per cent. less than that of the sine wave of that effective value.

It will be apparent from this reasoning that the effect of harmonics is entirely dependent on their phase relatively to the fundamental, and that attempts such as were made at the time of the "Sine Wave Controversy" to state generally the effect of harmonics in the P.D. wave on the iron loss of a transformer are quite futile.

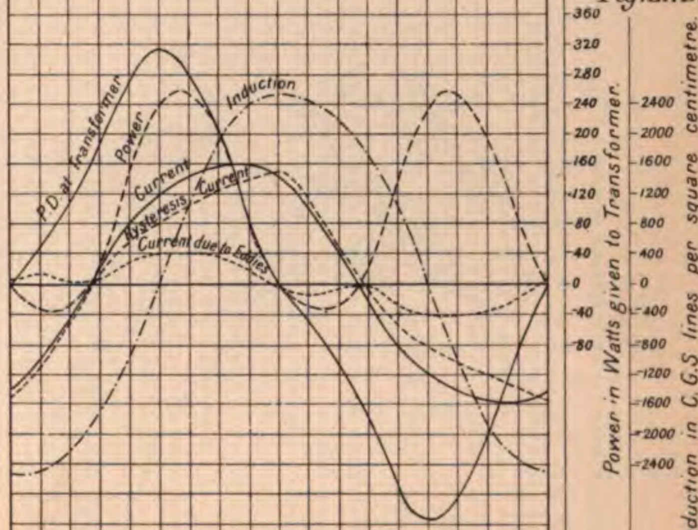
Professor Fleming.

Professor J. A. Fleming: As the authors have made some reference to opinions expressed by me, perhaps it is desirable that I should make a few remarks on the paper, if only to correct some views that I find attributed to me. In the first place, I should like to offer the criticism that I think the authors have not done quite sufficient justice to the work of Dr. Roessler on this subject. A very full account of that work was published some six months ago, in which Dr. Roessler described the investigations he had made with machines giving E.M.F. curves in different forms, in order to settle some of the points which have been dealt with in the paper under discussion. Practically, I think, he really covers the whole of the ground which the authors' experiments have occupied. Dr. Roessler pointed out clearly that the question of the hysteresis loss in transformers when worked off alternators giving different E.M.F. curves really depended upon the ratio between the R.M.S. value of the E.M.F. curve and the true mean value. That is also

I.A. Fig.III.B.



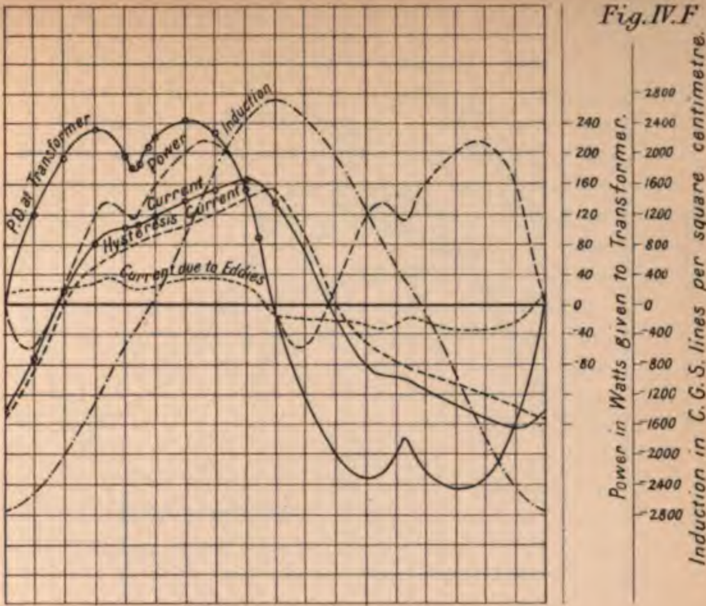
I.C. Fig.III.D.



load current, Induction, and Power curves
ons in the potential-difference wave-form.

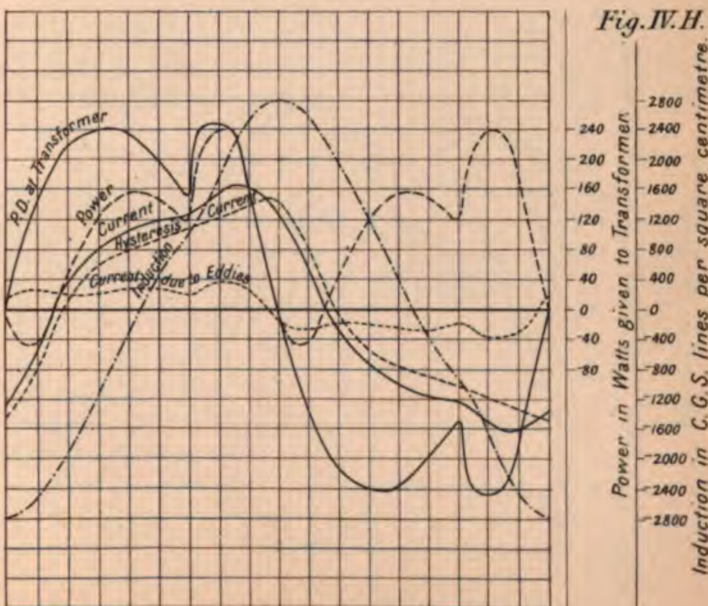
E.

Fig. IV. F



G.

Fig. IV. H.



oad current, Induction, and Power curves
ns in the potential-difference wave-form.

implied in the conclusions which are arrived at by the authors. Professor Fleming. The paragraph in which they sum up the whole of their results, pointing out that the loss depends upon the area of the applied P.D. curve, is only another way of saying the same thing. I myself found it convenient to define a term called the "form-"factor" as the ratio between the true mean value of the P.D. curve and the R.M.S. value, and stated the same conclusion by the use of that expression in recent Cantor lectures. All of us who are concerned with alternating-current work were quite familiar a long time ago with the fact that the form of the E.M.F. curve had a good deal to do with the power loss in transformers, and that, broadly speaking, the curves with a peaked or pointed form gave a less loss than those which had a more rounded or square form with the same R.M.S. value. In an early part of the paper the authors seem to imply that I held the opinion at one time that the sine curve P.D. gave the greatest loss. I had no intention of conveying that notion, for I know very well that it did not. It was merely a sentence of a letter written to *The Electrician* at a time when a controversy was going on in which some writers had suggested that machines giving sine curves gave the least loss, and I pointed out that experiments showed that that was not the case. Leaving these questions of priority, which are not very serious matters, the important question is, the practical results. The authors, I am afraid, seem inclined to minimise the value of experiments made with actual alternators. They say at the end of their paper: "We were anxious, however, to experiment "on the waves *not* actually met with in practice, since our aim "was not so much to find out which alternator now on the "market was the best, but rather to give some information, if "possible, which might be a guide in the future design of "alternators for use on transformers." The word "best," of course, is a very large word to use; most people, I think, would be prepared to admit that there was no *best* alternator outside the manufacturers' catalogues, but that each one had certain advantages of its own. In the selection of machinery for particular purposes we have to be guided by the end in view.

Professor Fleming.

Certainly I think we should all of us admit that, before it is possible to improve any existing apparatus, the first step is to know what the present forms are able to achieve; and, therefore, the most scientific process was to investigate with some care the behaviour of well-known and different types of alternators in this respect. That was what Dr. Roessler did. He took two machines of a well-known form—the Ganz and the Wechsler machines—and analysed their performance very carefully. My own attention was directed chiefly to the Mordey, Thomson-Houston, and Ferranti machines for the same purpose; because we may be quite certain that machines that have had so much experience and thought put into them have not been designed without good reason for each detail, and, therefore, any attempt to improve them must, at any rate, be preceded by a very careful study of their actual performance. As regards the power of improving any piece of machinery, everyone is well aware that in matters of this kind good design is generally a compromise, and that you cannot have all you want,—that you must be prepared to give up some things in order to get others, —and that the adaptation of the different portions of the design, one to another, must be governed by the end that you have in view. So it is with regard to this particular problem. It has been well understood now for a long time that a peaked form of E.M.F. curve gives the least loss, or a smaller loss, on the transformer, than does a curve with a more rounded form. Any manufacturer would be prepared to give you to-morrow morning a machine with a curve as sharp as you please; but that would be accompanied by certain other great disadvantages, because the secondary drop on transformers is increased thereby, and also with the increase of the maximum value of the curve so is a greater strain brought upon the insulation. Of the two sets of machines in one of the City of London stations, one of these types gives a thousand volts more maximum pressure than the other when working under some conditions, with the same R.M.S. value. Although the station voltmeter shows the same value on the machines, yet there is an absolute maximum of one thousand volts more in one case than in the other. There would be no total

advantage gained by purchasing a diminution in the core loss by a greatly increased secondary drop, and at the same time running the risk of breaking down half your cables every time you switch your machine on. Therefore, from the practical point of view—which, I presume, is the end we have in view here—the question of what form should be given to the E.M.F. curve must be governed, not only by the question of the loss in the transformer, but also by the question of the secondary drop, and the insulation difficulties involved. Therefore, summing up the whole of the matter, at the present moment my own feeling is this—that there is not a great deal which can be usefully done in that direction, because we know that we have these two conflicting results arising from altering much the E.M.F. curve. We can give it a little more peaked form, and in that way we can diminish the hysteresis loss of the transformer, but at the same time we are bringing ourselves into other difficulties. The machine which the authors have designed of course gives them the power of arbitrarily varying the form to a much greater degree than is found in actual practice. Although it is a common idea that an alternating-current machine has a particular wave-form attached to it, that is not the case at all; it often depends very largely on the nature of the load the machine is carrying, and on the armature reaction in that machine. Looking at it, then, from the point of view of the station engineer, we have to consider not only the questions involved in the form of the curve, but also the various other qualities which the alternator must possess. My own feeling at the present moment is that there is not much room for improvement in this direction. Something may be done; but, at the same time, as regards the diminution of losses in transformers, there is a great deal more to be gained by studying the transformer itself. and by improvements in the iron, than there is to be gained by dealing with the form of the E.M.F. curve. There is no doubt, however, that an apparatus which gives us the power of arbitrarily varying the form of the wave will have uses; and it is certainly a very much less expensive form than that which could be constructed by taking alternators with a large number of different bobbins

Professor Fleming.

Professor Fleming. attached to one shaft. I think it would have been a useful addition to the paper if the authors had been able to make some careful quantitative measurement by taking curves of widely different form-factors, having, of course, the same R.M.S. value for the E M.F., and then making exact measurements of the hysteresis loss in one and the same transformer worked off those different P.D. curves, and showing whether the form-factor—as I have called it—is actually proportional to this loss, or whether it merely increases with it. In some statements concerning the increase of core loss in transformers, some time ago, I guarded myself against the expression of opinion that it was precisely proportional to the form-factor, because at that time I had no means of actually proving it. If the authors, with the appliances at their command, are able to settle that point definitely, I think they will have added to our knowledge of the subject.

Mr. Rhodes. Mr. W. G. RHODES: With regard to what Dr. Fleming has just said, it may be of interest to see in what way the iron losses depend upon the *area* of the curve of potential difference between the terminals of the primary coil of a transformer.

The experiments described in Messrs. Beeton, Taylor, and Barr's paper were conducted with secondary circuit open, so that, very approximately, the potential difference between the primary terminals equals in magnitude the back E.M.F. of self-induction.

Let V = instantaneous value of potential difference between primary terminals;

A = cross-sectional area of core;

N = number of turns in the primary;

b = instantaneous value of the induction;

S = area of the V curve taken over half a period:

we therefore have

$$V = A N \frac{d\,b}{d\,t},$$

approximately.

Integrating this equation between suitable limits, as explained by the authors of the paper, we get

$$S = \int V\,d\,t = A\,N\,B \quad \ldots \quad \ldots \quad (1)$$

where B is the maximum value of the induction.

If we assume that the hysteresis loss, W_1, is given by Mr. Rhodes

$$W_1 = k_1 \, n \, B^a \qquad \text{(Steinmetz's formula)}$$

where k_1 is a constant, n the frequency, and a is a constant, we get, by substitution,

$$W_1 = k_1 \, n \left(\frac{S}{A \, N}\right)^a \quad \ldots \quad \ldots \quad (2)$$

If, further, we take the usual formula for loss due to eddy-currents, viz.,

$$W_2 = k_2 \, (n \, B)^2,$$

k_2 being a constant, then

$$W_2 = k_2 \, n^2 \left(\frac{S}{A \, N}\right)^2 \quad \ldots \quad \ldots \quad (3)$$

The total iron loss is therefore given by

$$W = W_1 + W_2 = \frac{k_1 \, n}{A^a \, N^a} S^a + \frac{k_2 \, n^2}{A^2 \, N^2} S^2 \quad \ldots \quad (4)$$

One of the authors of the paper pointed out that in the general case the eddy-current losses are proportional, not to B^2, but to the mean value of $\left(\frac{d \, b}{d \, t}\right)^2$ that is, to the square of the virtual potential difference. Equation (3) should therefore, to be perfectly general, be written,

$$W_2 = k_2 \times (\text{virtual P.D.})^2;$$

so that equation (4) assumes the form,

$$\begin{aligned} W &= W_1 + W_2 \\ &= \frac{k_1 \, n}{A^a \, N^a} S^a + k_2 \times (\text{virtual P.D.})^2 \quad \ldots \quad (5) \end{aligned}$$

If, then, the potential difference between the primary terminals, as measured by a hot-wire or electrostatic voltmeter, is kept constant, the total iron loss is given by equation (5), whatever be the *shape* of the wave.

The problem of finding the area of the wave which makes the iron losses a minimum, is the same as that of making the area of the P.D. wave as small as possible while the virtual P.D. remains constant. We have, therefore, to make

$$\int V \, d \, t \text{ a minimum}$$

while

$$\int V^2 \, d \, t = \text{constant}.$$

Mr. Rhodes. From this we deduce that $\int V\,d\,t$ has no absolute minimum, but may be made as small as we please, in the way indicated by the authors of the paper.

Mr. Evershed. Mr. S. Evershed: When I read this interesting paper a day or two ago, I rather felt, with Dr. Fleming, that from the point of view of the designer of alternators there was practically little to be done in the direction indicated by the paper; that is to say, it would hardly pay to design machines to give any different wave from those which are now in common use. But the whole subject of alternating-current machinery has been so involved in mystery, and so wrapped up with the sine wave, that a record of experimental work, such as has been brought forward this evening, is of the greatest value. It seems to me, however, that in dealing with the design of an alternator we have to think more of the man who is going to use it, the central station engineer, and he would at once ask, "What am I going to save? How many Board of Trade "units per annum am I going to save if I use machines giving an "efficient wave?" There are several companies in London at this moment which are delivering from two to three million units per annum to their customers. Suppose we take a station, therefore, of that size, and assume it to be an alternating-current station. We may assume that in any new system the transformers will be put in sub-stations, or, at any rate, "banked;" so that the total capacity of the transformers, whose cores must be magnetised day and night, would be possibly four million Board of Trade units per annum. If we take the differences in iron losses given in the paper for the different wave-forms, we find that, if we were to substitute for the present machines—which we might assume to be giving sine waves more or less—some type of machine which gave a better form—something analogous to Fig. 12 in the paper—I should say we could not hope to reach Fig. 12 exactly, although we may approach it,—we may reckon in practice that 10 per cent. of the present iron losses would be saved; that is to say, we might save 10 per cent. of the $2\frac{1}{2}$ per cent. now lost. The $2\frac{1}{2}$ per cent. on four million units works out at exactly 100,000 units; and we *might* save 10 per cent. of this, namely, 10,000 Board of Trade

units per annum. I need hardly say that we shall not save the 2d. or 3d. a unit, which those units cost to produce at the works, if they are not produced. All we shall save will be practically the coal and a little oil and waste, and things of that kind. If we put the total saving at 1d. a unit, I think it would be ample. Therefore we should save 10,000 pennies in the course of the year, or £42 per annum. But whatever saving may be effected in this way is at the expense of several minor disadvantages; for example, it is well known that machines giving a type of wave approaching Fig. 12, having sudden changes of induction, are subject to excessive vibration. I should like just to make one remark with regard to the curves shown by the authors for the eddy-currents. The shape of the eddy-current waves must be exactly the same as that of the P.D. wave; and that being so, the authors should look for experimental errors, or very possibly arithmetical errors, when they find any considerable dissimilarity between the two waves. I notice that in Fig. 3 A it is approximately the same shape; that is, it has a little lump at the beginning, just as the P.D. wave has; but in the other figures there are some obvious discrepancies. No doubt they have high authority for it, but I notice that the authors speak thoroughout of the R.M.S. value of current. I do not like that. We have all been so accustomed to speaking of "effective" current and "effective" E.M.F., that I must really enter a little protest against having a new phrase introduced. I think the word *effective* practically meets the case, and it is in very general use. I cannot sit down without congratulating the authors on the experimental skill which they have shown in a somewhat difficult investigation. Mr. Evershed.

Mr. TREMLETT CARTER: I disagree with Mr. Evershed, who has stated that the form of wave is not a practical question. I wish the discussion could be shared partly by American and partly by English engineers, as the Americans are taking a very great interest in this question, both from the theoretical and practical point of view. In fact, it was the practice of American engineers in building so-called sine wave alternators which first turned the attention of electrical engineers in England to the Mr. Carter.

Mr. Carter matter. At the present time, in America, where alternate currents are used for more diverse purposes than they are here, alternator builders are making and advertising alternators giving very different types of wave-form. They will offer a saw-tooth shape of wave for general purposes, and a flat-topped wave, curiously enough, for transformer work—just the opposite to that which the authors of this paper recommend, and have proved is the best for the purpose—and they will offer a simple sine wave alternator, practically without harmonics of any sort, for very long distance transmission. They contend that for long-distance transmission the absence of harmonics diminishes the line drop. I think, therefore, that this is a very practical question. I also think that the use of different kinds of waves in transfoımers should be decided by what the transformer is intended to do. A recent paper read by Mr. Frith before the Physical Society of London showed that for arc-lighting purposes the arc has the power of modifying the shape of the wave so as to make it a flat-topped wave when it is applied directly to the alternator, but that it has not that power of distorting the wave when it is run off a transformer of a lighting circuit. Consequently, for arc-lighting purposes, we ought to consider what type of wave we are going to send into the transformer, and we should use a different type of wave from that which we require if we are going to use transformers for general supply or incandescent lighting. I have not had time to study the paper thoroughly, and am unable at this early stage to criticise it in detail; but I congratulate the authors both on their development of the subject from the engineering point of view, and for the ingenuity with which they have devised apparatus to obtain their results and to draw the conclusions which they have so lucidly brought before the meeting in their paper.

Professor Ayrton. The CHAIRMAN (Professor Ayrton): I am sorry that Dr. Fleming has left, because I should have liked him to have been present when I spoke on this subject. I do not as a rule advocate a retrograde movement, but in this particular instance I would like you to put yourselves back into last June, and consider what was then the knowledge on this subject—not, of course, what ideas may have

been in some of our minds, but what information was actually published at the time. Professor Ayrton

Dr. Fleming had made experiments on the change that was produced in the iron losses in transformers by a variation in the shape of the P.D. wave, and in June last he published as his conclusion that "the iron core loss in any transformer was "greatest on that alternator the E.M.F. curve of which most "closely approximated to a sine wave." It was but fair, therefore, for the authors to say to themselves, "If that is the "case, then we may draw a very important conclusion. If the "sine wave be really the most inefficient to employ, let us use "a *very flat* wave." I do not think they have laid sufficient stress on this consideration in their paper. We all know what Dr. Fleming has told us this evening: that certain dynamos, having the same R.M.S.—with all deference to Mr. Evershed—P.D. wave, may have a very much higher maximum which may break down the insulation. We know that. Let us go in the other direction: let us use a flat wave; let us employ a wave that will not have a high maximum and which will not break down the insulation, and then, according to Dr. Fleming's published conclusion of June last, we shall also have an efficient wave for a transformer.

It was as much that consideration as anything else that they set themselves to try and test by experiment the following:—"Is it true that a very flat wave, which is a very safe wave—and "a wave which Dr. Roessler showed some time ago was an "efficient wave for *arcs*—is also an efficient wave for *trans-"formers?* If so, it is the very thing to use."

The experiments described in the paper of this evening do not support this deduction, but, on the contrary, they lead to the conclusion that, so far from a flat wave resembling a peaked wave in being more efficient than a sine wave, the sine wave does not stand out as being particularly inefficient, and that it is a mistake to suppose that whether you go up or down from a sine wave,—whether you employ a more or a less dangerous wave,—you obtain increased efficiency. The authors have, in fact, shown that if you go up you no doubt increase the danger, but you obtain greater

Professor Ayrton.

efficiency; whereas, if you go down, and flatten your wave, as in Fig. 11, then the increased safety is accompanied with much smaller efficiency.

In reading the paper I think it was a mistake that Mr. Taylor, in order to save time, omitted to read what is stated about Dr. Roessler's work. As the paper was read it did appear as if Dr. Roessler's researches had been slurred over, but that is not the case in the paper itself. You must also remember that, as a matter of fact, these researches of Dr. Roessler's—or, rather, the publication of these researches—followed the experiments which have been described this evening; and that the conclusions which the authors have given you this evening they gave to me, and doubtless also to many of their companions, before any of us knew anything of Dr. Roessler's work on transformers. I do not think, therefore, that a complaint can be made that full justice has not been done to Dr. Roessler's investigations.

You may, however, ask, Why, if the authors obtained these results, did they not publish them at once? I am afraid I am personally to blame for that, and I am sure Mr. Carter would say I am extremely to blame; because the authors of this paper were desirous of publishing these investigations in *The Electrician* about the middle of last year, in continuation of their articles in that journal describing their "injector" and its uses. Had they followed their own suggestion, and doubtless Mr. Carter's wishes, the paper would have appeared at once, and there would have been no question of precedence. It was I who advised them to keep the paper back (not knowing, of course, of the investigation that was being carried out abroad), and to offer it to the Institution of Electrical Engineers. We were unable to hold the first meeting of the Institution announced for this session because this building was not ready at the time; then followed a long period devoted to the study of house-wiring; so that it was only quite recently that it was possible to bring this paper before the meeting. Therefore, although it may seem that the authors have allowed a considerable time to elapse before presenting their results, the explanation is a simple one, and, as I am personally responsible, I

should be very sorry if the delay diminished the credit due to them for their research. Professor Ayrton.

With reference to their very ingenious instrument, the "injector," of course in laboratories, when many people are working together, some younger and some older, the ideas may sometimes come from the older to the younger. In this case, however, the idea and the carrying out of the injector is absolutely their own. I quite agree with what Dr. Fleming and the other speakers have said—that it is a valuable instrument, and an economical instrument for enabling us to obtain any shaped wave. Mr. Taylor did not mention a very important point, although it is contained in the paper. He said that condensers were expensive, and, as he left the matter there, you might think that the injector only represented a small fraction of the total cost, and that a very large extra sum had to be spent in buying condensers. The authors have, however, pointed out in the paper that the greatest change in the wave is produced by the use of the very smallest capacity, and, therefore, that you need not add to this apparatus any costly adjuncts. The great value of the authors' device is simply that it enables you to make a wave exactly in the way that you draw a person's face. Supposing that you are drawing a straight line—say the line of the forehead—then you do not impress a number of different impulses—a number of different harmonic motions—on your hand, because presently the pencil has to be moved out to the left, say, to draw the nose, and then, later on, back again farther to the right to form the mouth. On the contrary, when you wish to draw the forehead, you draw it,—when you wish to draw the nose, you do so,—without the necessity of all the time combating an influence to draw the mouth or form a chin in the middle of the nose

The injector method, in fact, of producing a hump, or a depression, in a series of waves at exactly the same spot desired, and leaving the rest of the wave-form practically unchanged, differs radically from the method which various people have tried of combining harmonic motions to represent, with more or less accuracy, a complicated wave-motion. For the latter method is as much more complicated than the former as trying to produce

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darkness by the interference of various lights is more troublesome than simply turning the light out.

We must congratulate the authors on the success of their instrument, and of its application to the examination of the iron losses in transformers; and I think we must especially congratulate the one who read the paper—Mr. Taylor—for, from the clear and energetic way in which he did so, you would not imagine that for some time past he has been confined to his bed by illness, and that he only went out of doors for the first time the day before yesterday.

Mr. Barr.

Mr. JAMES MARK BARR (in reply): Let me say that Professor Ayrton has so very admirably replied to parts of Dr. Fleming's criticism that there is little more to be said upon the points touched. But there is one portion of Dr. Fleming's criticism which calls for emphatic rejoinder. He would have our words mean that we wished to avoid dealing with machines in practice, because we were searching for some new and imaginary "*best*" alternator which would necessarily be quite distinct in design from all dynamos now in use. I wish to say that our first interest and enthusiasm for the wave-form investigation were raised by the part Dr. Fleming took in the sine-wave controversy, and we felt with him that actual trials with a larger number of wave-types than theretofore used would bring useful knowledge, whether or not the "*new*" and "*best*" dynamo would be a result.

In June of last year we published an account of a method for producing different wave-forms, and pointed out that we could make exact reproductions of the normal waves of known different dynamos.

Now, before our article was completed in *The Electrician*, Dr. Fleming sent a long letter to the editor giving an account of his own work in the line of *artificial* wave production, and he spoke of the special interest he felt in the subject. We were led to believe that he would before long show us the excellent results of his interest in wave-form work, and he said: "This has by no "means the abstract interest which many have supposed, but has "a very practical aspect in connection with alternate-current "working."

Nothing appeared. One is now forced to feel, after hearing Mr. Barr. his pessimistic views this evening, that Dr. Fleming has lost his enthusiasm. The reason seems not forthcoming. In his letter of June, 1895, we read: ". . . we are now, happily, in the condition in which current curves of different kinds can be 'made 'to order,' and the problem before is how to make to order the most economical shape."

And this evening Dr. Fleming says: ". . . I think that we should all of us admit that, before it is possible to improve any existing apparatus, the first step is to know what the present forms are able to achieve; and, therefore, the most scientific process was to investigate with some care the behaviour of well-known and different types of alternators in this respect."

I certainly agree with Dr. Fleming that this is the first step.

In the paper we have just read we have taken the *second step.*

When our paper was first written we had before us what we supposed to be the only reliable results published—the preliminary results of Dr. Fleming, mentioned briefly, but very distinctly, in his letter of June 28th, 1895, in *The Electrician.* He had taken the first step. And Prof. Ayrton has pointed out to you the conclusions which might be drawn from the statement in that letter.

Now, although, as I have mentioned, we pointed out how we could copy normal types of waves, when we proceeded with the second step, as we are now forced to call our work, we felt it necessary to deal with wave-forms of large and radical differences, if we would establish firmly the manner of change in iron loss with variation of wave-form. We felt that, theretofore, when anyone had experimented on the effects of different wave-shapes (using, as he must, the machines of practice), he had been beset with this difficulty—indeed, danger—that for the same R.M.S. value of volts he did not get much difference in the shape of the waves or in the areas.

We had noticed, among hundreds interested in the subject, that results with waves of practice did not differ much, and

Mr. Barr. therefore we asked ourselves, "Are not these differences due less "to the variations in wave-shapes than to experimental errors?" In experimenting with several separate machines, you all know that the difficulty of keeping the conditions similar and constant in all cases is immense. We decided to go further than merely doing away with these difficulties, both scientific and economical. We proceeded to supplement the known tests, such as they were, with waves exaggerated toward both extremes from the sine shape—waves very flat and waves very peaked. In order to establish the validity of a law we must take advantage of relations of the more marked effects, and deal with quantities differing by values as large as can be obtained.

Suppose now, after a long and heated controversy on the subject dealt with this evening, we humbly put before you results which give some decision. Should there then be any justification in minimising the *raison d'être* on the plea that *other* questions need elements of decision?

For example, when one reads Dr. Fleming's article of last July, entitled, "Thermo-electric Powers of Metals and Alloys between the "Temperatures of the Boiling Point of Water and Liquid Air," one realises that the paper has reason for being in spite of the existence of burning questions of far greater human importance in many spheres of thought. *Anything* which increases our knowledge or affirms a doubtful assumption is important.

The article just referred to is valuable because greater variations of temperature than usually found in practice are taken so that the curves showing the laws of variation already found, with usual ranges, are then checked for accuracy. A bit of a parabola, for instance, is hard to recognise as such. But extreme conditions give results which show the complete and real tendency of the observed law-curves.

I would, in conclusion, call your attention to the curve in Fig. 10, shown you early this evening.

Mr. Taylor. Mr. C. PERCY TAYLOR (in reply) said: I should like, if I may, to add a few remarks to what Mr. Barr has said. I should like, first of all, to thank many of the speakers for the kind manner in which they have criticised our paper. In the remarks which

Dr. Fleming has made he has really considered a far larger Mr. Taylor
problem than we have attempted to solve. The question which we have tried to answer is *not*, "Which is the best P.D. "wave for the alternators of a central station distributing "electrical energy by means of transformers?" *but*, "What "is the law connecting the iron losses of transformers with the "shape of the applied P.D. wave?" This is clearly stated in our paper. Dr. Fleming said that practically the effect of wave-form on the iron losses in transformers was a small one in the question of central station economy. We are well aware of that fact (although Dr. Fleming does not seem to think so), but, so long as it *is* one of the conditions governing central station economy, it seems to me that it must be an advantage to obtain more information about it. It is evident that the best compromise must necessarily result from the most accurate knowledge of all the conditions involved. We have not attempted to deal with the other conditions governing choice of wave, but we have shown clearly towards the end of our paper the limitations which the insulation difficulty puts on transformer efficiencies. I would also point out that, until the question had been investigated, it was impossible to say whether an economy might not be effected in transformer losses *without* the introduction of other difficulties.

I cannot agree with some of the figures which Mr. Rhodes has put on the board. I do not think that the eddy-current loss is proportional to the square of the maximum induction. I think it is proportional to the mean value of $\left(\frac{d\,B}{d\,t}\right)^2$—that is, to the square of the effective P.D. In the first place, we consider that our experiments show that; and, in the second, if the eddy-currents can be considered as equivalent to one secondary current—which we believe to be the case—the thing is self-evident. Dr. Roessler also showed, from purely theoretical considerations, that the eddy-current loss depends only on the R.M.S. value of the P.D.

I quite agree with Mr. Evershed that the eddy-current component of the current-curve should have a shape exactly similar to the P.D. curve; the irregularities of our curves are due, in

Mr. Taylor. my opinion, to the cause we mentioned in our paper—the complicated method by which they were obtained. Our reason for using the term "R.M.S." instead of "effective" is that the latter has another meaning, namely, that part of the E.M.F. in a circuit which is used in overcoming ohmic resistance. The term we used also has the advantage—and it is no small one in these days of rapid advance—of showing its own meaning.

I am sorry that I omitted to read that portion of our paper which deals with Dr. Roessler's work. I was trying to pick out of the paper those parts which were of the most importance, in order to allow time for discussion. We found Dr. Roessler's paper very interesting, and I certainly meant to do no injustice to him.

Dr. Fleming is not yet convinced that the hysteresis loss is "directly proportional" to the P.D. form-factor with a constant R.M.S. value. By "directly proportional" we presume he means "solely dependent upon," because, as a matter of fact, the hysteresis loss *decreases* with increase of form-factor, and it is not even inversely proportional to it. In our humble opinion, the curve given in Fig. 10 of our paper goes some way to prove that there *is* a direct relation between the hysteresis loss in a transformer and the form-factor of the applied P.D. wave. I should like to point out, however, that, since the iron loss is made up of two parts, the hysteresis loss itself can only be obtained by one of two methods—either by a calculation of the maximum induction, which practically assumes what we are trying to prove, and hysteresis tests such as we have made; or by assuming the eddy-current loss constant with a constant R.M.S. value of P.D., which, again, has at present only been experimentally proved by means of the former assumption.

Professor Ayrton. The Chairman: I am sure you will have great pleasure in according a hearty vote of thanks to the authors for the very interesting communication they have given us this evening.

The vote was accorded unanimously.

The Chairman: I have to announce that the scrutineers report the following candidates to have been duly elected:—

Associates:

A. S. Anderson.
Frederick Ernest Andrews.
R. B. Johnson.
Alfred J. Hollington.
James Patchett.
Frederick S. Pilling.
Thomas Scott.
John Henry Whittaker.

Student:

William Collins.

The Two Hundred and Ninety-first Ordinary General Meeting of the Institution was held at the Institution of Civil Engineers, 25, Great George Street, Westminster, on Thursday evening, May 28th, 1896—Dr. JOHN HOPKINSON, M.A., F.R.S., President, in the Chair.

The minutes of the Ordinary General Meeting held on May 14th, 1896, were read and approved.

The names of new candidates for election into the Institution were announced and ordered to be suspended.

The PRESIDENT: This is the last meeting of the session, and it has been usual on these occasions for the names of new candidates to be balloted for. Is it your pleasure that that should be done on the present occasion?

Agreed to.

The following transfers were announced as having been approved by the Council:—

From the class of Associates to that of Members—

Wilfred D. Bailey. | S. V. Clirehugh.
Martin Hamilton Kilgour.

From the class of Students to that of Associates—

Gordon Paton Clark.	G. E. Sperati.
Arthur Edward Mayes.	G. E. Wright.
H. H. Pickford.	R. J. Jocelyn Swan.

Donations to the Library were announced as having been received since the last meeting from Messrs. Macmillan and Messrs. Spon, to whom the thanks of the meeting were duly accorded.

Mr. H. G. Wood and Mr. A. P. Haslem, Associates, were appointed scrutineers of the ballot.

The following paper was then read :—

THE UTILISATION OF WATER POWER, ESPECIALLY WITH A SMALL FALL, WITH SOME EXAMPLES OF PLANTS FOR THE GENERATION OF ELECTRICAL ENERGY.

By Alph. Steiger.

The cheap production of electrical energy is generally recognised to be one of the chief aims of modern engineering science. Mr. Steiger.

Nature has provided us in water power with one of the best possible agents for realising this object; and I trust that, in bringing the subject of the utilisation of this free gift of Nature before the members of the Institution of Electrical Engineers, I shall be able to convince them that the water powers of this country, if judiciously utilised, are capable of rendering them great service.

In my own country—Switzerland—the electrical engineer is co-operating cordially with the water-power engineer, and electrical installations are rapidly increasing in number. The successful electrical transmission of power to points far distant from its source has been the chief factor in this development.

The idea prevails that considerable fall is required to obtain water power, but it is my desire to show and *to prove* in the following remarks that excellent results are obtainable also with a very low fall—a fall of even less than 3 feet.

Small falls are more frequently met with in this country than high falls, and will, therefore, have more particular attention in this paper than the high falls found in mountainous districts. The description of a few turbine plants under low falls, some of which are applied to the generation of electrical energy, will be of special interest.

During a long experience in constructing turbines and designing complete plants, I have found that the most difficult were always those connected with the utilisation of a low fall. These difficulties consist chiefly in the variation within very wide limits of both the quantity of water and the fall,

Mr. Steiger. while a constant power, and in most cases a constant speed, is of great importance.

Generally speaking, the real agent in water power is gravity, and the water is simply the medium to transmit the action of gravity on to the motor which converts it into mechanical work. The action of gravity can take either the form of dead weight, or of pressure, or of velocity, sometimes called kinetic energy. A very high efficiency is obtained from motors in which the water acts by dead weight or by pressure, but the slow speed of the water-wheels and the complicated mechanism of the pressure engines render them unsuitable for the purpose of generating electricity; moreover, motors worked by weight or by pressure are only advantageous when working under a high fall.

The kinetic energy is the only form in which the gravity can be applied advantageously to the performance of mechanical work under a small fall. The motors using it in this form are the common undershot wheel, the Poncelet water-wheel, and the turbines.

It will be sufficient for the purpose of this paper to give the efficiency of the various types of water motors for any fall, without going into a detailed description of those which are unsuitable for driving dynamos. The efficiency of the motors, with the fall for which they are adapted, is as follows:—

Fall. Feet.	Efficiency of Water-Wheel.	Per cent.	Efficiency of Turbine. Per cent.
1 to 5	Ordinary undershot...	25 to 30	70 to 75
	Poncelet	65 to 70	
	Sagebien	65 to 75	
5 to 8	Low breast	30 to 50	75 to 80
8 to 15	High breast	60 to 75	75 to 80
15 to 50	Overshot wheel ...	65 to 75	75 to 80
Above 50	Pressure engine ...	75 to 85	75 to 80

These figures show the interesting fact that, the smaller the fall is, the greater is the gain in power over the old-fashioned water-wheels. Although the smallest fall which would reasonably be utilised by a turbine is at least 2 feet 6 inches, I

will show by some examples that, by a turbine suitably constructed and carefully adapted, useful power is still obtained under a fall of only 1 foot or a little over. Mr. Steiger.

The great variety of fall, water supply, local conditions, and special requirements, of necessity demands a variety of types of turbines.

Turbines are classified, according to the manner in which the water acts in them, into—

(*a*) "Impulse," or "action," turbines, and
(*b*) "Reaction" turbines;

and according to their construction, into—

(*a*) Parallel flow turbines,
(*b*) Radial flow turbines,
(*c*) Mixed flow turbines.

There is an essential difference between the "impulse" turbine and the "reaction" turbine, as indicated by the form of vanes illustrated in the diagrams Fig. 1 and 2.

FIG. 1.—Vanes of "Action" Turbine.

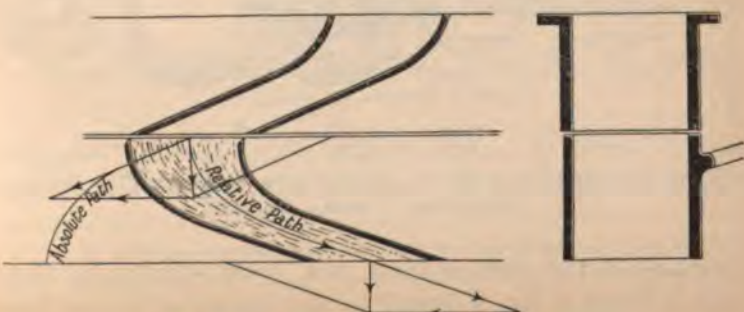

FIG. 2.—Vanes of "Reaction" Turbine.

Mr. Steiger. *The "impulse" turbine*, as usually constructed, must run clear of the tail-water, its buckets being only partially filled with water. It requires a constant fall, with constant level of the water in the head and tail race, but its efficiency is not affected by the greatest variation of the water supply.

On account of this quality, it can be built as partial injection turbine, to utilise high falls with a very small water supply. If constructed as "partial injection turbine," its diameter can be chosen so as to give just the desired number of revolutions. This is extremely convenient for driving dynamos, which can thus be connected direct with the shaft of the turbine, doing away with intermediate gearing or belt drives. An instance of

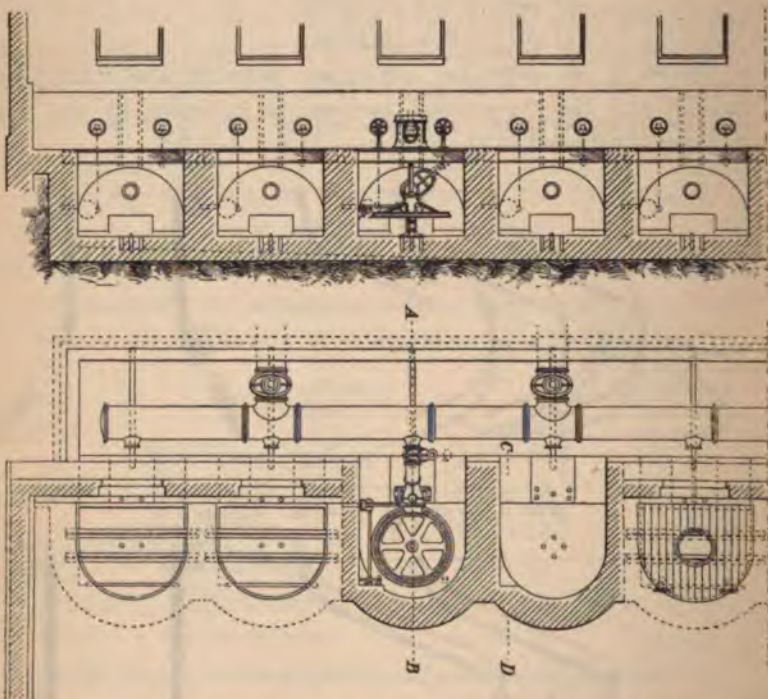

Fig. 3a.—Turbines at the Factory of Foyers, Scotland. (The British Aluminium Company, Limited.)

this kind is the turbine plant now being erected by Messrs. *Escher*, Wyss, & Co., of Zurich, at the Factory of Foyers, for the

British Aluminium Co., Limited.* This plant consists of five Mr. Steiger.

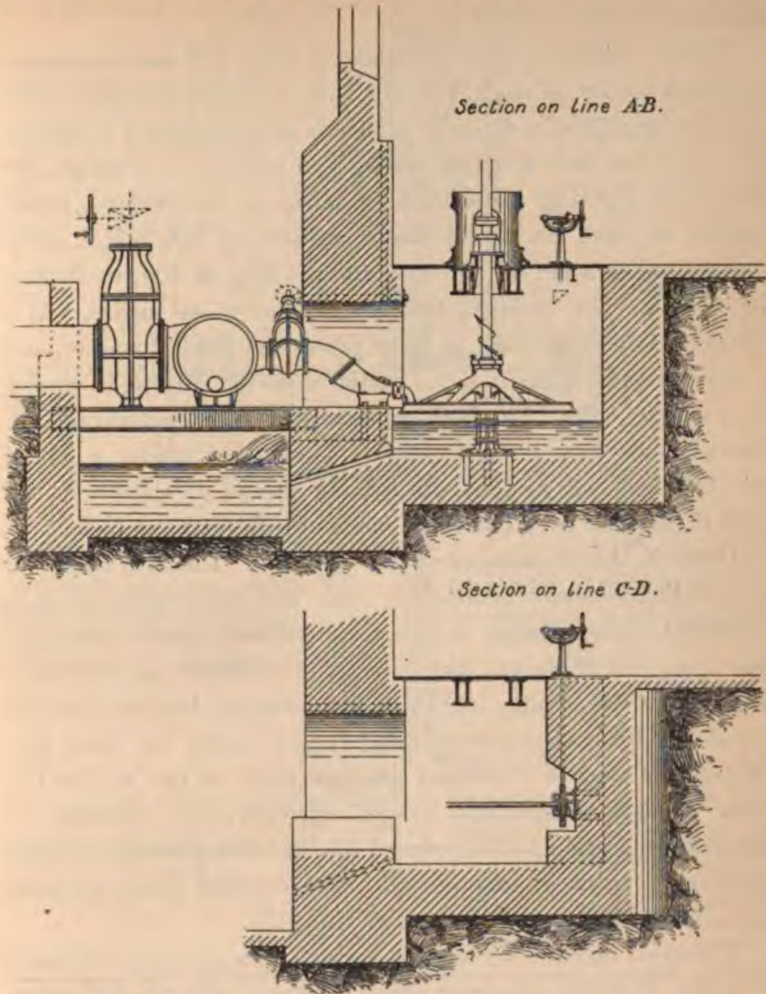

Fig. 3b.—Turbines at the Factory of Foyers, Scotland. (The British Aluminium Company, Limited.)

"impulse" turbines with vertical shaft, with partial injection, each giving 700 brake horse-power, working under a fall of 350

* The plant as executed is different from the above drawing in so far that each turbine has its own pipe, and that the tail-race is on the opposite side to the inlet.

Mr. Steiger. feet. The dynamos are required to run at 140 revolutions per minute, and to obtain this speed the turbines were given a diameter of a little over 9 feet.

Partial injection turbines under a high fall are sometimes fixed on a horizontal shaft, and can thus be coupled direct to the armature spindle of a dynamo by means of an isolating coupling. This mode has been adopted, amongst numerous other plants, for the electric lighting installation of Davos, in Switzerland, which consists of three horizontal patent turbines of 200 B.H.P. each, working under a fall of 330 feet, and running at 400 revolutions per minute. The turbines have a diameter of 40 inches. As a contrast to these turbines of large power and small diameter, and to show the adaptability of the partial injection turbine to special requirements, the 140-H.P. turbines of the waterworks in Chauxdefonds may be mentioned. These work under a fall of only 170 feet, but as they are driving pumps at the low speed of 60 revolutions they had to be made of a diameter of 15 feet.

Great as the advantages of the "impulse" turbines are under the conditions above mentioned, their use under very low falls is limited, firstly, owing to the reason already given that they must run clear of the tail water—a condition which can seldom be realised in a flat country like this; and, secondly, because they run at a slower speed than a "reaction" turbine under the same fall. Although "impulse" turbines are now built to run in the tail water without considerable loss of efficiency, the reduction of power in proportion to the reduced fall, and the quantity of water accordingly reduced, together with the reduced speed, excludes them in the majority of low and varying falls.

The ideal turbines for low and varying falls are *the "reaction" turbines.* They are generally placed in a level with the tail water, or, if local conditions require them to be placed above tail water, connected with it by a suction tube. They run at a higher speed for the same fall, or the same diameter, than an "impulse" turbine, and their efficiency is not affected by the immersion in the tail water. The principal objection raised against "reaction" turbines in general is that their efficiency is greatly reduced when working at part gate. This is indeed the case with many of the

Mr. Steiger.

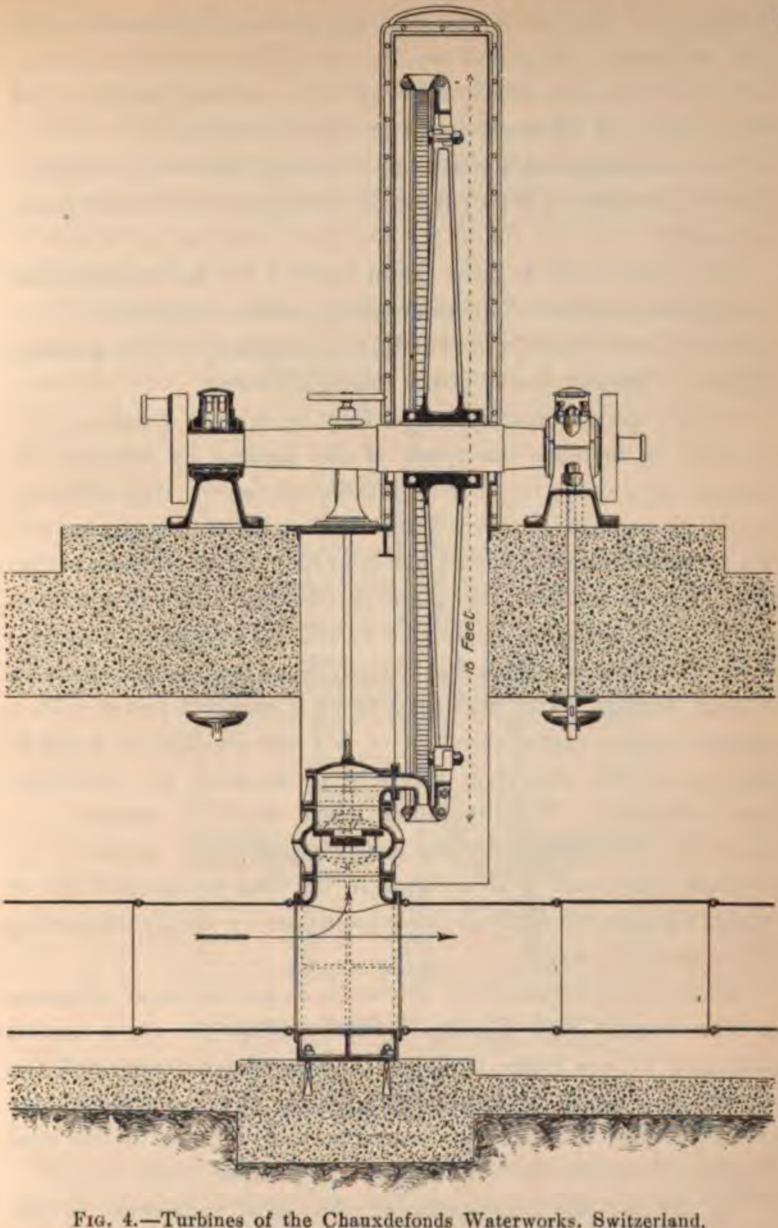

FIG. 4.—Turbines of the Chauxdefonds Waterworks, Switzerland.

reaction turbines known in this country, which give a very poor efficiency at part gate, especially at less than half gate. The

Mr. Steiger. continuity of flow of the water through the buckets is essential to a good efficiency. Only in a few reaction turbines is this condition fulfilled to such an extent that within very wide limits of the water suppy the efficiency is not perceptibly reduced.

The utilisation of a small and varying fall, with a varying quantity of water, is a very difficult problem for the water-power engineer.

The turbine for a given power under a low fall is larger and runs slower than one of the same power under a higher fall; it is, therefore, heavier and more costly, and requires heavier gearing, entailing a greater loss of power through friction.

A high speed is desirable, especially for driving dynamos; but attempts to increase the speed of the turbine by reducing its diameter may easily result in an inferior efficiency. The efficiency should be as high as possible in consideration of the greater cost of a water-power plant with a low fall; but the proportions within which such a fall and the quantity of water varies is mostly so great that it is almost impossible to obtain the highest efficiency when the water supply is diminished, *i.e.*, when a high efficiency is most wanted. The maintenance of a *constant* power with a *constant* speed under variation of fall and quantity of water in large proportion can, if at all, only be attained by sacrificing some efficiency. The hydraulic losses must be reduced to a minimum by the most careful construction of the turbine in its essential parts, and it is needless to say that no standard size or type of turbine will fulfil all these conditions by simply consuming all the available water.

Even the arrangement of the turbine chamber is of influence on the results, and requires special attention. On a careful judgment of the local conditions depend the economy and the success of a plant. Unsatisfactory results in water-power plants are caused just as much, or oftener, by bad judgment of the local conditions than by the inferiority of the turbine.

In by far the most cases of low falls, incidental to flat countries, an abundance of water corresponds with a reduction of the fall. The power of a turbine calculated for the normal fall *would be* reduced, for the time, when an abundance of water

reduces it, and, as a consequence, water would be wasted, while the power obtained is insufficient. These cases are, unfortunately, of frequent occurrence. On the other hand, if the turbine is constructed to give off the required power under the reduced fall, it must be partially closed for the diminished water supply with the normal fall, whereby the efficiency would be reduced just when it should be highest, if economy is at all the chief object of a turbine plant. Mr. Steiger

The manner in which a high efficiency can be maintained for a diminished water supply is to subdivide the turbine into several compartments, each of which represents a complete turbine.

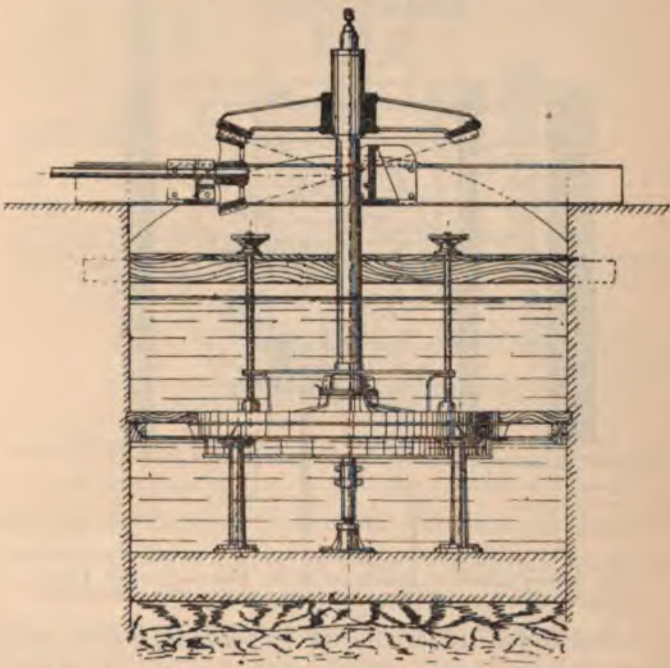

Fig. 5a.—Turbine at Brantham Mills, Essex—Cross Section.

This arrangement has been adopted by Fourneyron for his well-known outward flow turbine, and in the modern *Jonval turbine*. The Fourneyron turbine is provided with a cylindrical gate, which is moved vertically, whereby each compartment is opened or closed. This type has been adopted for the large-power plant on

Mr. Steiger. the Niagara Falls, but on the European continent they are seldom used. Their efficiency is very good, but, owing to the narrowness of the buckets, they are easily choked.

The Jonval turbine is a parallel flow turbine, and is, for large variations of the fall and quantity of water, subdivided into two or more concentric compartments. A subdivision in this manner renders it possible to maintain not only the power, but also *the speed*, under a varying fall within very wide limits.

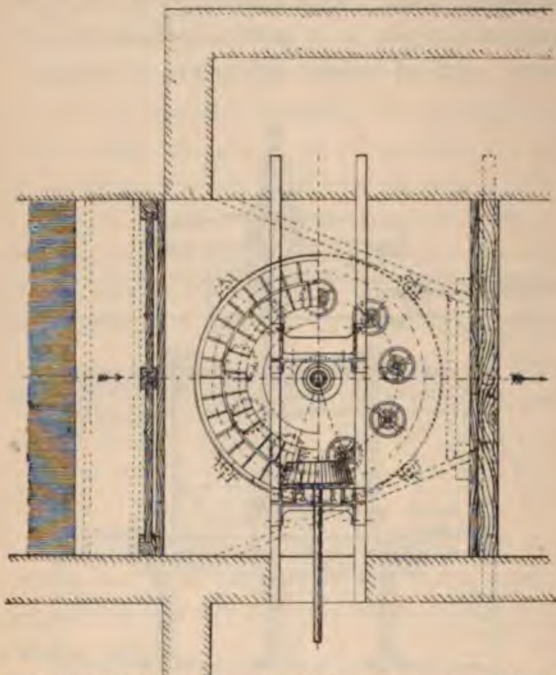

FIG. 5B.—Turbine at Brantham Mills, Essex—Ground Plan.

The description of a Jonval turbine installation which I supplied for the Brantham Mills, near Manningtree, in Essex, here illustrated, will show that a very small and varying fall can be utilised with great advantage to obtain nearly a constant power. The local conditions and requirements are most remarkable and interesting. The power is used to drive a modern flour mill, in which the maintenance of a regular speed is of equally great *importance* as for driving an electrical plant.

The river Stour is a tidal river, with a maximum fall at ebb tide of 4 feet 10 inches, while at high tide the fall is *nil.* The water is supplied partly by the river itself coming down from the hills of Cambridgeshire, and partly by the rising tide filling the river-bed above the mill for a considerable length. The power required is 40 actual H.P., and it was stipulated that this power should be maintained down to a fall of 40 inches. On starting the turbine, it was shown, however, that it drove the mill at full Mr. Steiger.

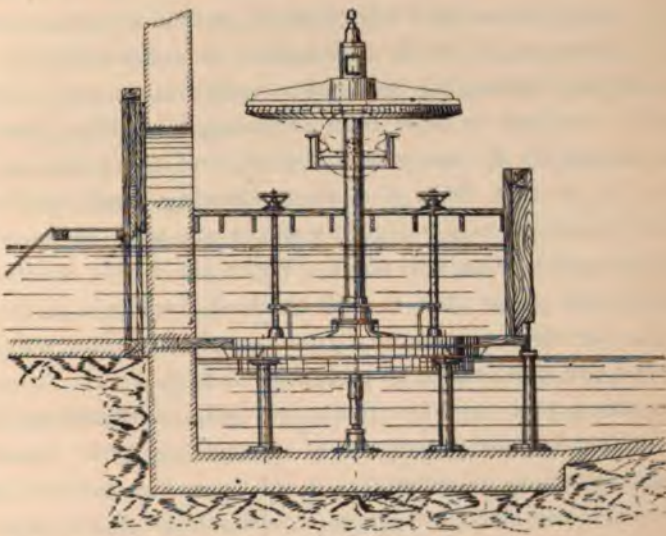

Fig. 5c.—Turbine at Brantham Mills, Essex—Longitudinal Section.

capacity and at full speed under a fall reduced to 32 inches. The full power is available during 16 hours of each day, while during six further hours the power corresponding to a fall reduced down to about 1 foot is still utilised for driving a part of the machinery. Comparing the useful power obtained from this varying fall by the new turbine during 24 hours with that obtained by the under-shot water-wheel previously working, it is nearly six times larger.

The turbine consists of only two concentric rows of buckets; the inner one is provided with gates, which are opened or closed by hand wheels, an automatic governor not being generally used in flour mills. The outer row of buckets is just large enough to

Mr. Steiger. give the full power required under the maximum fall. As the fall is decreasing by the rising tide, the gates of the inner row of buckets are gradually opened to make up the power by an increased quantity of water, and the more water is passing through the buckets of the inner row the more it acts on a reduced mean diameter, thus maintaining also the proper speed without perceptible loss of efficiency.*

The power is transmitted from the turbine on to a horizontal main shaft by means of a pair of bevel wheels. This horizontal shaft is made to run at 75 revolutions, and is provided with a clutch by means of which the turbine is connected with the steam engine if the mill is required to work continuously. When the fall is reduced to more than 32 inches, the mill is, however, driven separately by the steam engine, and the power of the turbine is used to drive the wheat-cleaning machinery, and eventually some pairs of millstones which can work independent of the automatic roller mill plant. When the fall is reduced to 15 inches, the power that is still obtained from this turbine is 7 H.P., the turbine naturally running slower; but still this power is quite sufficient to be profitably utilised.

Assuming that the water power available at Brantham Mills were applied for the generation of electric energy, it would, in the first instance, be necessary to obtain a conveniently high speed to drive an electrical generator without much intermediate gearing. A turbine similar to the one actually working could be made for exactly these conditions, running at 30 revolutions per minute, and a pair of bevel wheels put in of such proportions as to give the first motion shaft a speed of 150 revolutions per minute. This speed would be very suitable to drive a dynamo of 40 H.P. by means of a belt or ropes. A higher speed of the turbine than 30 revolutions would, for such a low fall, only be obtainable at the expense of efficiency. As in this special case the fall, and consequently the power, varies with the rise and fall of the tide, the full power of the turbine can, of course, only be relied on

* The outside diameter of this turbine is about 10 feet, and it runs with 24 revolutions per minute.

during 15 or 16 hours every day. The power produced during the time when the fall is diminished beyond the limit at which it is 40 H.P., and at less than the normal speed, could probably be applied to charge electrical accumulators. Mr. Steig

The construction of the turbine shaft deserves some notice. The space underneath the turbine being always filled with water, and, therefore, inaccessible, the pan for the footstep is placed on top of a column round which the hollow cast-iron shaft revolves. The upper part of the turbine shaft is widened, and contains an adjustable steel pin which revolves in the pan or cup, filled with oil. Although a well-constructed footstep will last for years without requiring repairs, an easy access to it is of great advantage.

Similar turbines were erected by me in other mills near Norwich, Reading, and Lewes. In all cases the fall varies between (23 inches) 2 feet 6 inches and 6 feet, the reduction of the fall being caused by floods, while the water supply varies in the proportion of about 1 to 4. In each case the local conditions were carefully investigated and the turbine constructed accordingly. The good results obtained in each case are due to the careful *adaptation* of the turbine to the conditions. The importance of a careful consideration of local conditions is evidenced by several failures which were recently brought under my notice. In one of these instances, the turbine—which in itself is a very good motor—gives very poor results owing to the disregard of the actual conditions of the locality. Even the construction of some details of a turbine depends sometimes on these conditions, and in several cases now under consideration I have had to depart from the general practice of designs of turbines, in order to secure the highest results when most required.

How varied the construction of a Jonval turbine may be, will be shown by the following examples.

The turbines of the Geneva Waterworks, built by Messrs. Escher, Wyss, & Co., of Zurich, work under a maximum fall of 12 feet during the winter season, when the water supply is shortest, while during the summer season the water supply stored up in

ir. Steiger.

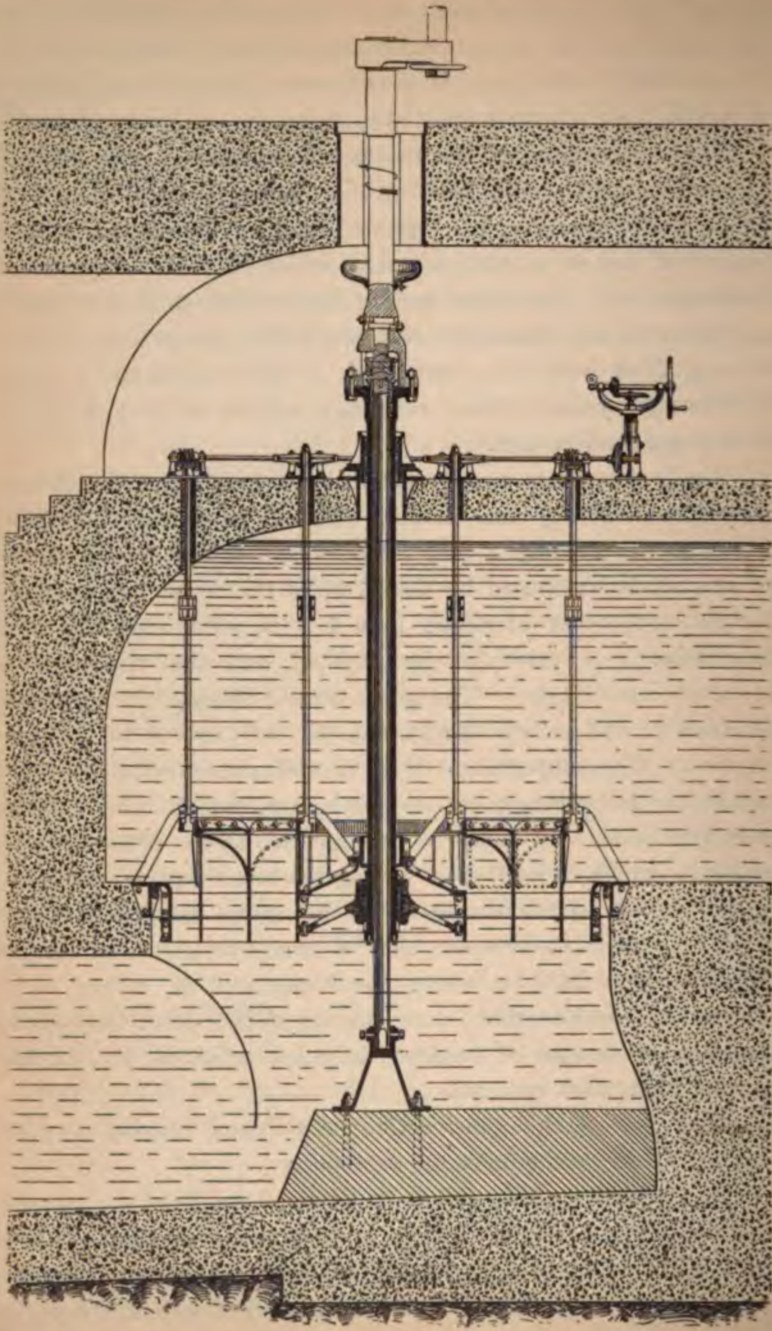

Fig. 6.—Turbines of the Waterworks, Geneva.

Mr. Steiger

the mountains, in the shape of snow and ice, is abundant. The large summer supply reduces the fall, however, to 5 feet 7 inches. The power of each turbine, of which there are now 17 at work, is 210 actual H.P., and they run at a uniform speed of 36 revolutions per minute, whether the fall is 5 feet 7 inches or 12 feet. The cost in this case was a secondary question; the turbines have, therefore, been provided with the best possible arrangements to suit the large variations of the fall and quantity of water.

The drawing shows three concentric rows of buckets. The outer row alone will develop 210 H.P. under the maximum fall of 12 feet—its outside diameter is 14 feet Each of the two inner rows of buckets is provided with a revolving gate, working separately. Each turbine drives a pair of double-acting plunger pumps direct, the crank common to both pumps being fixed on the vertical turbine shaft.

An interesting turbine installation, under a fall varying from 10 feet 9 inches to 8 feet 10 inches, in connection with electrical generators, is that at Baden, in Switzerland. It was described in *Engineering* of November 1st, 1895. This plant was erected to supply the town of Baden with electric light, and the necessary driving power to the new works of Messrs. Brown, Boveri, & Co, the well-known electrical engineering firm. The fall had to be created by a weir, and a canal about 2,500 feet long, which added considerably to the cost of the plant. Each of the three turbines is of the Jonval type, giving off 200 B.H.P. It is impossible to build a turbine of that power for the fall available in this case, which would run with a speed high enough to drive a generator direct. The turbines run at 40 revolutions per minute, which speed is maintained under the varying fall by means of gates for the inner row of buckets. The generators—two-phase dynamos of the horizontal type, made by Messrs. Brown, Boveri, & Co.—run at 200 revolutions per minute, and are driven direct off the turbine shaft by means of a pair of bevel wheels. The exciter dynamos, of which there are three of 10 H.P. each, are driven each by a separate turbine. These small-power turbines naturally run at a higher speed—namely, 180 revolutions per minute—and drive, therefore, the exciter dynamos without any intermediate gearing.

Mr. Steiger. In most cases in this country where a good water supply is available, the fall will be rather lower than 10 or 12 feet; it will therefore require intermediate gearing to drive a high-power generator, and it will even not often be possible to connect it direct with the first main shaft driven off the turbine by bevel wheels. Belt drives are very convenient to get up the necessary speed of dynamos, but for large power they are very expensive, and absorb a considerable amount of the power in friction. The ordinary round hemp and cotton rope is objectionable, on account of requiring frequent repairs and re-splicing. During an inspecting tour in Switzerland last summer, I came across a new kind of hemp rope, which seems to supply just what is wanted to drive large-power dynamos. A piece of this patent rope is here for inspection. It is a plaited rope of extreme pliability, which does not stretch. I found this rope working at the generating station of Schaffhausen. The power at the generating station is transmitted from the countershafts, driven off two turbines of 300 H.P. each by means of bevel wheels, on to the generators by means of 10 such ropes, $1\frac{3}{4}$ inches thick. The rope pulleys on the dynamos have a diameter of 5 feet, running 300 revolutions per minute. The rope pulleys on the countershaft have a diameter of 13 feet 6 inches, and the distance between the centres of shafts is 51 feet. The power is electrically transmitted to a spinning mill about half a mile distant from the generating station. The secondary station consists of an electro-motor of 200 H.P., coupled directly to a main line shaft, and two electro-motors of 190 H.P. each, coupled together. The latter, running at 300 revolutions per minute, carry a rope pulley of 5 feet diameter with 14 grooves. 100 H.P. are transmitted by four such ropes to a shaft 21 feet above the electro-motor, at an angle of 51°, while the remaining 250 H.P. are transmitted to another shaft on about the same level and 17 feet 8 inches distant, running with 130 revolutions per minute. In spite of the unfavourable relative position of the shafts, these ropes work with extreme regularity and easiness, and their adaptation has, according to the manager of the spinning mill, put an end to the

trouble and frequent stoppages caused by the breaking of the round ropes which were previously used. Mr. Steiger.

Returning to the description of water-power plants proper, two more examples in connection with the generation of electricity deserve to be mentioned, showing how certain objects can be attained by a special construction. One of these is the installation of five new turbines for the aluminium works at Neuhausen,

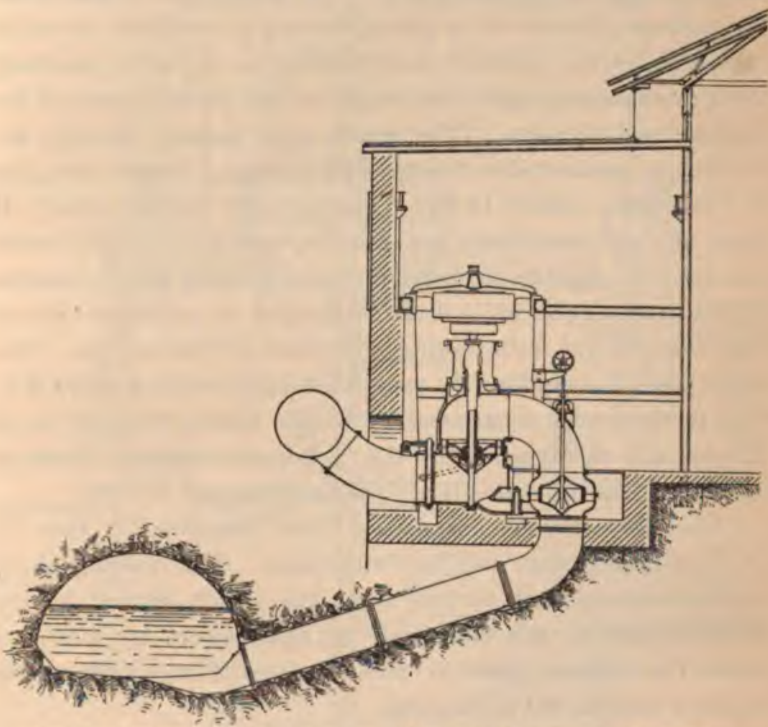

Fig. 7.—Turbines of the Aluminium Works at Neuhausen Switzerland.

on the Rhine fall, in Switzerland. One of these turbines is here illustrated. Each of these turbines gives off 610 B.H.P. under a fall of 66 feet, with a quantity of water of 6,500 cubic feet per minute.

With the high fall a high speed suitable for driving the dynamo direct is naturally obtained—an arrangement which has also been adopted in this case to economise space. On the other

Mr. Steiger. hand, the load on the footstep of a turbine of the power mentioned by the pressure of the water, in addition to the weight of the armature of a generator of corresponding dimensions, is so great that a special arrangement had to be adopted to release the footstep of at least a part of that load. In order to overcome this difficulty, the turbine has been reversed, the water passing through the turbine upwards, acting, therefore, in the opposite direction to the weight of the machinery. The boss of the turbine wheel is, moreover, formed into a piston, working in a cylinder, to which water under the pressure corresponding to the fall is admitted, thus counteracting again the weight of the moving parts of the turbine and dynamo. The water, after passing through the turbine, is conducted to the tail-race through a suction tube, the turbine being placed 15 feet 9 inches above the tail water. It runs at 150 revolutions per minute, and is a single Jonval turbine. To regulate its speed, if required, a ring gate is inserted in the suction tube, while it can be stopped by a throttle valve in the wrought-iron tube taking the water to the turbine. The total power now utilised by these aluminium works is 4,550 H.P. The turbines were constructed by Messrs. Escher, Wyss, & Co., of Zurich, and the dynamos by the well-known electrical works at Oerlikon. Each dynamo is of 7,500 amperes and 55 volts.

The last turbine installation here illustrated is that at Zufikon-Bremgarten, also in Switzerland. The drawing shows another arrangement to counteract the weight carried by the footstep, and at the same time an arrangement by means of which the necessary speed to drive a dynamo of large power direct under a medium fall is obtained.

The plant consists of four sets of double Jonval turbines of 325 B.H.P. each, running at 115 revolutions per minute, and a smaller Jonval turbine of 34 B.H.P., driving two exciter dynamos, running with 210 revolutions per minute, and was erected to supply electric light to the neighbouring town of Wohlen, and driving power to the new works of Messrs. Escher, Wyss, & Co. in Zurich, and a large flour mill close by these works. The distance over which this power is transmitted is about 11 *miles.*

The fall is 17 feet 6 inches, and was obtained by building a dam across the river Reuss, and a tunnel about 1,100 feet long across a hill round which the river flows at a rather high speed. The water is divided between two Jonval turbines fixed on one Mr. Steiger.

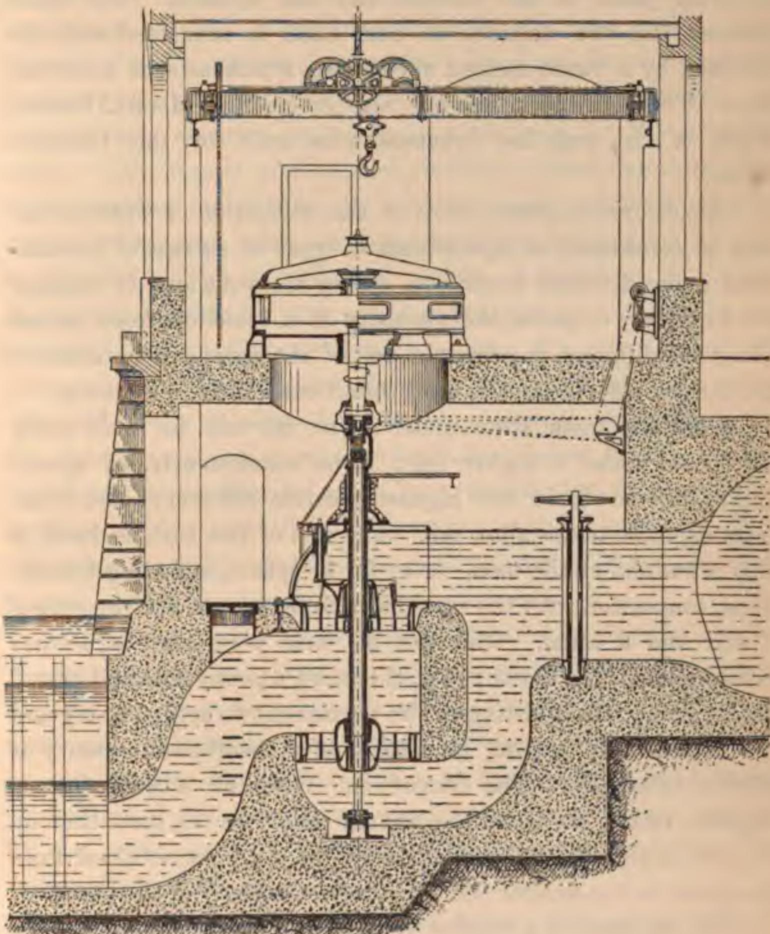

Fig. 8.—Turbines at Zufikon-Bremgarten, Switzerland.

common shaft so that it passes upwards through the lower wheel and downwards through the upper wheel. By distributing the water in this manner, the diameter of each turbine is reduced, and the speed consequently increased. At the same time the

Mr. Steiger. pressure of the water, which would otherwise act on the footstep, is entirely counterbalanced. The central part of the lower wheel is, moreover, formed into a disc, on which the water presses from below, releasing the footstep also partly by the weight of the revolving parts of the turbine and the dynamo. The space between the two turbines on each shaft is connected with the tail-race by a flume formed of concrete, which acts as a suction tube. This turbine plant was also erected by Messrs. Escher, Wyss, & Co., and the dynamos were built by the Oerlikon works.

The examples given above of the utilisation of water power may be considered as representative types of successful installations under different conditions. They are sufficient in number and in variety to prove the necessity of a selection from motors which are different in principle, and of the careful adaptation of the turbine selected to the local conditions and requirements.

A turbine installation under a low fall will be more costly than one under a higher fall; it is, consequently, of special importance to obtain the highest possible efficiency, even at an extra expense, under a low fall. The cost of the turbine itself is only a fraction of the total outlay for the plant, including foundations, connection with the machinery to be driven, and sometimes a weir and a canal. The cost of these permanent structures exceeds that of the motor; it is, therefore, a penny wise and pound foolish policy, after putting in the permanent structure, to try and cut expenses by putting in a turbine of insufficient capacity or inferior efficiency. The commercial value of a water power depends rather more on the annual outlay on the same than on the first cost, and the annual outlay for the work obtained from the power is the smaller the higher the efficiency of the plant.

The efficiency of a turbine which can be obtained and honestly guaranteed, even if the fall is low, is about 75 per cent. Eighty per cent. and a little over is sometimes obtained under favourable conditions, and has been proved by careful tests made by responsible experts; but an efficiency of 85 and 90 per cent., sometimes claimed, is never reached, if the quantity of water be *accurately measured* during the test. If the efficiency of the turbine is

guaranteed at all, it should be stated not only for the most favourable conditions, but also for a reasonable *minimum* of the fall or the quantity of water. Mr. Steiger.

In many instances within my own knowledge, water power, in itself sufficient to drive the machinery of a factory, but improperly utilised, is supplemented by artificial power, produced by steam, gas, or oil engines. The loss of money caused by the waste of the cheap power from a running stream in this manner amounts certainly to a big sum in this country alone. The annual cost of such auxiliary power, calculated for 3,000 working hours, may be put at three to four times the cost of water power, and calculated for 6,000 working hours, four to eight times the cost of water power. A judicious utilisation of the water power in such cases would not only result in an enormous saving of money, but in a gain of a large amount of power now unutilised. Most factories are closed at night time, when the water is allowed to run away without being made use of. Assuming that the water power is insufficient to drive all the machinery in the daytime, while it is wasted during the night, electrical storage batteries in connection with a generator might very advantageously, and perhaps with greater economy, be used instead of auxiliary steam, gas, or oil engines.

It seems probable that in the near future the electrical transmission of power will take the place of shafting and belt drives in factories, when certainly the waste of water power would be prevented in the manner suggested. Owners of factories driven by water power might even find that by improving their water power they obtain spare power which could be profitably applied by the generation and distribution of electrical energy in the immediate neighbourhood.

I may add that the majority of large-power central stations now being erected in Switzerland for the generation and distribution of electrical energy are mostly utilising small or medium falls varying between 10 to 30 feet. The storage of water in the shape of snow and ice on our mountains provides us with a good water supply during the summer, but the low temperature in winter reduces that water supply very considerable.

Mr. Steiger. The water power there is just as variable as in other countries, and those falls which can be advantageously utilised on account of being situated in the inhabited and industrial districts are often not any higher, or not much higher, than in this country; the only difference being that such small falls occur more frequently, rendering a concentration of large power in one place easier, and perhaps less costly. Still, it is my conviction that concentration of water power for the distribution of electrical energy, or for the generation of a large amount of electric current, as required for electro-chemical and electro-metallurgical processes, is possible in many places in this country without going into prohibitive expenditure for canals, &c.

In conclusion, I hope to have succeeded in my endeavour to show how water power under low falls can be, and is, very advantageously and economically utilised for the generation of electrical energy; and that a very large amount of water power is now running to waste which could, in conjunction with electrical machinery and apparatus, be turned to profitable account by such a hearty co-operation of the electrical and the water-power engineer as has resulted in such success of commercial enterprise in my native country.

Mr. Carter Mr. Tremlett Carter: I had wished that someone more competent than I could have opened this discussion, but there are a few remarks I should like to make relative to the utilisation of low falls for electrical purposes, especially in this country. In the opening part of his paper, Mr. Steiger promised to prove the utility of low falls; and at the close he says he hopes that he has succeeded in his endeavour to show that low falls can be economically used for electrical generation of power. I trust I may be pardoned if I fail to appreciate Mr. Steiger's logic. In his paper he has given us a number of examples of the utilisation of water power. He has given us, first of all, the case of the Falls of Foyers, where the fall is 350 feet. Next he described the works at Chauxdefonds, and told us that there the fall is "only "170 feet." A description of Brantham Mills follows, and at that place the fall is quite low—only 4 feet 10 inches; but that is at a

flour mill, and the turbine makes only 24 revolutions per minute. Mr. Carter. This is quite an impossible sort of turbine to apply to a dynamo, without having a considerable loss of power between the turbine and the dynamo, owing to gearing being required. Then Mr. Steiger mentions the Geneva Waterworks, with a minimum fall of 5 feet 7 inches, which is also a non-electrical example. Then he gives us the case of Baden, where there is a 10 feet 9 inches fall. That is certainly an electrical installation, but he has told us nothing as to the initial cost of the plant, nor as to the results obtained. He next cites the Neuhausen Aluminium Works, where the fall is as great as 66 feet; and, finally, the installation at Zufikon-Bremgarten, with its 17 feet 6 inches fall. I am bound to say that the data and figures with which Mr. Steiger has furnished us in these few examples do not amount to a proof—indeed, are very far from showing—that low falls are useful for electrical purposes in this country.

Mr. Steiger has rightly stated that England is the land of low falls,—that high falls, or even moderate falls, are rare. Now there are certain complaints from which the low falls of this country often suffer. There is the complaint of too little water, which occurs in dry weather; but that is nothing to the complaint of *too much* water, from which mills commonly suffer. I have more than once seen desirable mill sites completely laid under a vast sheet of water—head-race, tail-race, I was going to say the entire mill, completely drowned out; and the cause of this calamity was never more than a little extra heavy rain. This is very common; or, when it does not occur to such a terrible extent, it often happens that the tail-race becomes "tailed up," or flooded to such an extent that the turbines will not work. Frost is also the cause of much trouble, the stream, mill-pond, and everything else becoming frozen up and impossible to work. Another serious complaint arises from the principle of "first come, first "served," which obtains on most of our rivers and streams. I will give you an example of this. A small electric supply station with which I am acquainted was driven by undershot water-wheels, with steam stand-by plant and secondary batteries—quite a complicated affair. A short distance up stream, above this

Mr. Carter. station, there was a flour mill. Now your flour miller is nothing if not thrifty; so, before he left the mill in the evening, the owner of that mill shut down the main sluices and saved up the entire river all night, in order to have plenty of water in the morning. But the electric lighting station wanted the river in the night and could not get it. You cannot run a water-power station if the man next door up stream has switched off the river. If you want to run the station in the night you must dig a mill-pond large enough to store up half a day's worth of river. At the station I am speaking of it was impossible, for special reasons, to dig such a pond; so they had to put in steam stand-by plant and a large storage battery plant; and we all know how very inefficient it is to rely to such a large extent upon secondary batteries. These are some of the difficulties and troubles which I and others interested in the utilisation of low falls in this country have often encountered; and it will readily be seen that such difficulties entail the erection of stand-by steam plant capable of taking the whole load, and this enormously increases the initial expenditure upon the undertaking. It does not duplicate the cost quite, because steam plant is cheaper than low-fall water-power plant, for any given power; but the horse-power must, of course, be duplicated.

Even if we have a low-fall mill site from which all these defects are absent, we still are met with the difficulty that an enormous quantity of water, per unit of energy, will have to be dealt with, as compared with a high fall. I will give you an example which I have worked out. Suppose we wish to have 1 kilowatt at the station switch-board, with a water-power generating plant working under a fall of only 3 feet, and with an over-all efficiency between the turbines and the switch-board of 50 per cent. Mr. Steiger will agree with me, I think, that that is a liberal allowance of efficiency, taking into account that on such a low fall it will be necessary to have double or treble reduction gear, belts, &c., in order to get the necessary high speed for the dynamos. On such a fall, under the conditions I have stated, about 3,000 gallons of water per minute would be required, in order to deliver 1 kilowatt at the switch-board. Now let us

take the case of a 350-feet fall, such as that at the Falls of Foyers. Mr. Carter. Here it would be quite easy to have as high an efficiency as 70 per cent. between the turbines and the switch-board. In that case only 18 gallons of water per minute would be necessary, per kilowatt—18 gallons as against 3,000 gallons. You will readily see that to deal with that enormously larger bulk of water, in the low-fall installation, it will be necessary to build larger and more expensive water-courses and engines. Moreover, to handle so large a volume of water by means of a governor will not be easy. It is more difficult to get close governing on any water-power plant than in a steam engine; but where the fall is low and the volume of water is large, close governing is so difficult as to be well-nigh impossible. Even with well-balanced regulator sluices the range of motion in governing is so large that hunting is sure to take place if the load varies largely or suddenly, as it will in an electric lighting station.

Still speaking from the electrical point of view, I take exception to Mr. Steiger's advocacy of impulse turbines on moderately high falls. Mr. Steiger has quite rightly, in my opinion, condemned the use of these turbines on low falls, where the tail level is likely to vary; but I believe they are unsuited for any class of fall where dynamos are to be driven, except, perhaps, such exceptionally high falls as that at Comstock, in America, where the head is over 1,000 feet, and where the speed of a reaction wheel would be such as to be prohibitive both for dynamo and for turbine. Mr. Steiger has said that at the Falls of Foyers, where partial admission impulse turbines are used, the type of turbine was chosen because the dynamos required to be run at a certain low speed. Had reaction turbines or total admission impulse turbines been adopted, the dynamos would have had to be run much faster. Now I totally disagree with Mr. Steiger that this practice was necessary. It is not the business of such dynamos to want to be designed to run at any particular speed whatever. The proper line to follow in designing such a plant is to select a convenient speed for the turbine to suit the mill site, and as high a speed as possible, and then to design the dynamos so that they will run direct-coupled to the turbines.

Mr. Carter. Gearing, of course, ought to be avoided. But the objections to the partial injection impulse turbine extend further than this. Such a turbine really consists of several turbines, one only of which is at work at any given instant. If water is admitted over only one-fourth of the circumference of the turbine, then practically there are four turbines, of which three are idle at any moment; and the weight and cost and friction of the turbine will be proportionately raised. Moreover, impulse turbines cannot be balanced against one another so as to take the load off the footstep pedestal of the shaft, as can be done with reaction turbines, and as is shown in the diagram of the Zufikon-Bremgarten turbines, in Fig. 8. If you will look at the diagrams of the turbines at the Falls of Foyers, you will see that not only is the pressure of the water not taken off by an equalising pressure, but that all the downward pressure is applied at one side of the rim of the turbine; so that there is a heavy downward tilting force, which prevents smooth and easy and efficient running, and which absorbs considerable power and involves great strengthening of the parts.

Finally, I think that we ought to face this question of the utilisation of low falls, not merely from the point of view of the possibilities of engineering design in triumphing over variations of fall, &c., but from the point of view of the relative costs of such water power, and coal or gas or oil engine power. And when we regard the question in this light I do not think that we in this country often find that it wears the roseate hue with which Mr. Steiger has fondly painted it. Mr. Steiger has told us that water power is the free gift of Nature. Perhaps he is right,—in a certain sense he *is* right; but it is often a free gift with a legacy duty of 100 per cent.: one cannot get much comfort or profit out of it. And when we consider all the initial expenses, and the difficulties and troubles involved in keeping the water-power plant running, and the need for stand-by plant of a reliable kind, we shall prefer in most cases, I venture to think, to be content with coal and steam power, which we have to pay for, in place of the water power which we get so freely when it is wet weather.

Mr. Siemens. Mr. Alexander Siemens: I think we should certainly thank Mr. Steiger for telling us what has been done in Switzerland; and

even if the falls of the various installations cannot exactly be called low falls, I think his paper proves quite sufficiently for our purposes that the low falls are adaptable for driving steadily, as in the case of the Manningtree Mills. But if I say that, I say really all that Mr. Steiger has been able to demonstrate to us in favour of low falls. He says these mills are run about 16 hours a day—that is, they have two interruptions of four hours—a tidal interruption; and this tidal interruption is not regular every day, therefore you have to provide some power supplementary to the free gift of Nature. Mr. Steiger has brought his paper before us with the view of teaching us that water power is applicable to electric driving; but he should not forget that it was Lord Armstrong who, nearly 20 years ago, put up at his private house a small installation with water power to light his picture gallery (that was before the days of incandescent lights), and at the same time he had a motor driving a lathe or a saw. I believe that the original installation is at work even at the present day. Then in the year 1881 the town of Godalming was lighted by low-fall water power. There was a mill with all the advantages described by Mr. Carter which was utilised for driving the dynamos; and Godalming has certainly the distinction that it was the first town in the whole world which had all its streets lighted by electricity, and which had lights distributed to private houses where required. But, unfortunately, there was very little demand, and the thing was not a financial success; it was before its time. The drawback here in England of utilising water power is that you cannot rely on it,—you cannot work with it alone,—you must have something to fall back upon; and the moment you have that,—the moment you have to put up a steam plant, or whatever it is, capable of dealing with the whole of the lighting,—then why complicate it by having water plant alongside? I am sure the English engineers are quite as much awake to the beauty of water power, where water power is attainable; but the low falls in England are, as far as I can judge, not adapted for electric lighting. Mr. Siemens.

Mr. Shoolbred: I wish to name to the meeting an example of a low fall, which the author had omitted to mention—that at Mr. Shoolbred.

Mr. Shoolbred.

the well-known Menier's chocolate works, at Noisiel, near Paris. The case is a peculiarly difficult one, as the fall there varies from about 5 feet 6 inches to, at times, as low as 15 inches; and the whole of the river Marne is there dealt with. What makes it, perhaps, more interesting in the present discussion, is that the turbines are of the Girard "impulse" type—turbines which the author in his paper has stated are difficult to manage with low falls. Those turbines have been working there for many years. There were originally three of them, each specially adapted to a different amount of fall. The largest of them, suited to the very low fall, is as much as 23 feet in diameter. This one has, we are now informed by Dr. Silvanus Thompson, been recently replaced by an undershot water-wheel.

"Impulse" turbines, though not suited to general use, have certain special advantages. Under certain circumstances "reaction" turbines, especially with low falls, where they are apt to be drowned by floods, may be found to be more useful on the whole. Most of the author's examples of the "reaction" class are confined to the Jonval "parallel" flow turbine. There is, however, a "reaction" inward flow turbine which has been used in this country, and with much favour, for many years—that of the late Professor James Thomson, brother of Lord Kelvin; its efficiency is about 75 per cent., as has been fully demonstrated by tests carried out by the late Professor Rankine, and others.

The author, in illustrating the value of the water power of the low falls in Switzerland, has overlooked the fact that the circumstances under which the water supply is obtainable there, especially as regards the period of the year, are *precisely the opposite* to what they are in this country. It is stated in the paper, that it is in summer especially that the largest supply of water is available in Switzerland, and then in a regular manner, owing to the melting of the snow and ice; while in this country the greatest difficulty in dealing with low falls is either the absence of water in summer, or else, as Mr. Carter has mentioned, from excess of it, through being flooded out, and thus being deprived of any fall at a certain time of the year. It is this absence of regularity in the supply of the water power that renders it difficult in this

country to utilise hydraulic power with advantage, as we engineers would most certainly be only too glad to do, if only on account of its cheapness. But if we are bound, as Mr. Siemens has pointed out, ultimately to fall back upon steam power as a stand-by in times of drought or of flood, then comes the question, Why complicate the installation, and add to the capital outlay, by having two sets of plant, one of which is lying idle for about half the year? Mr. Shoolbred.

Mr. M. Mowat, late M.L.C., Bombay: When I came into this room I had no intention of speaking on the subject of the lecture; but as a leading member of a company at the present time one of the largest, if not the very largest, user of water power in Her Majesty's dominions, a few remarks may be of some interest. I have to thank Mr. Steiger for the valuable paper which he has just read, and I quite agree with him that there is a great deal of power running to waste which might be utilised to great advantage in the interests of the company. I believe the time will come, and it is not very far distant, when water power will be far more utilised than at present. Now I will tell you a little about what I know regarding water power. One of the previous speakers referred to Mr. Steiger's showing what was going on in the utilisation of water power, without giving results. I can, from experience as a merchant, speak as to results. Mr. Mowat.

It is now many years since my firm—Messrs. Ritchie, Steuart, & Co., of Bombay—obtained a lease from Government of the power at the celebrated Falls of Gokak, on the Ghataprabha River, in the Southern Mahratta country, India. We have got a fall of nearly 200 feet, are employing five turbines of 250 H.P. each, have set up three more of the same capacity, and ultimately intend to work up to 4,000 H.P. We drive two large cotton mills containing nearly 50,000 spindles, have a capital of £200,000, and calculate that there is a large saving through the use of water power, by which the shareholders of the Gokak Company benefit. At present we employ about 1,300 hands. The cost of the water-power installation, with turbines and wire ropes (the mills being one-eighth of a mile from the falls) was about £22,000—engines, boilers, and chimneys would have cost more—

Mr. Mowat. and the rate we pay for water shows a vast saving when compared with fuel. The turbines and motor machinery were supplied by Messrs. Escher, Wyss, & Co., of Zurich, whom Mr. Steiger represents in London. The Swiss have always made water power a speciality, and I observe that Messrs. Escher have got the contract for the Falls of Foyers plant.

Mr. Steiger refers to some who let the water run away at night, but I may tell you that we are not of those. We find it necessary to husband what runs into the lake and channel over night, so that it may be available during the next day. We use the waterfall for electric lighting with success. As the increased use of water power must to a large extent be measured by its commercial success, I have pointed out one. Self-interest governs most commercial affairs in this life; and if you can use water power to give more profitable results than steam, the cheaper motor will carry the day. I am glad this Society has taken up the matter; and I have no doubt the more water power is looked into, and the more it is used, it will prove a source of wealth to our country.

Mr. Esson. Mr. W. B. Esson [*communicated*]: It is to be hoped that the author of the paper will not treat too seriously the remarks of the first speaker, which amount merely to this—that the engineer should weigh carefully all the conditions of the water supply before deciding to instal a turbine plant. I think the paper, being of such a thoroughly practical character, is a valuable one; for though we may be all alive to the advantages of employing water power whenever we can make it pay, it is distinctly of service to bring all the arguments for water power together and within the confines of a single paper.

I am glad to see that Mr. Steiger emphasises so strongly the necessity for considering all the local conditions when designing turbines, for I am sure that to the custom of using stock patterns—often irrespective of the conditions under which the wheels are to work—is to be attributed the poor results which are sometimes obtained. It is in Switzerland, where water is abundant, that the construction of the turbine has received the greatest amount of scientific study; and a knowlege of the manner in which the

various water-power problems occurring in practice are attacked Mr. Esson. and solved by a firm of such world-wide reputation as Messrs. Escher, Wyss, & Co., cannot be other than of the greatest use.

But, having said this, I want to point out that what appears to me to be one of the most important points in turbine engineering has not been alluded to: I refer to the question of the governor. In describing the plant at Brantham Mills, Mr. Steiger says that the gates "are opened or closed by hand wheels, "an automatic governor not being generally used in flour mills;" and though, as he further states, "the maintenance of a regular "speed is of equally great importance as for driving an electrical "plant," the nature of the work in the two cases I conceive to be widely different. I am not very familiar with flour-milling, but it has always struck me as being a pleasantly regular process, and subject to extremely small variation in the power required from minute to minute. Again, I imagine—subject, of course, to correction from Mr. Steiger—that, a given number of machines being at work, any possible variation could only be a small fraction of the total power, seeing that a very large percentage of the latter is absorbed in the mere driving of the machinery irrespective of the material passing through. For this reason it is easy to keep the speed uniform, and, as there are no sudden calls for additional power from time to time, the gradual opening of the gates by hand as the tail water rises furnishes a perfectly satisfactory solution of a comparatively simple problem. Now with electric plant it is different, especially in power transmission work. Here the variation in power requirements may be sudden and irregular, and some governing device becomes, in consequence, essential to the successful working of the installation. I suppose a whole treatise might be written on the subject of turbine governors, though I much doubt if at the present moment a wholly satisfactory governor exists. The great difficulty has been to get a sensitive governor sufficiently quick-acting to prevent a dangerous rise of speed without putting excessive strain on the water pipes, and I trust that in his reply Mr. Steiger will supplement a paper already valuable with some information on this apparently neglected matter.

Mr. Esson. I have lately had some valuable experience in transmission work and driving by turbines. At the Sheba Mine, in Barberton, S.A.R., Messrs. Johnson & Phillips have recently erected a plant for the delivery of 300 horse-power at a distance of 5 miles from the generating station—the first long-distance transmission of any magnitude, it may be remarked, in the South African Republic. Unlike any other mine of which I have knowledge, the Sheba Gold Mining Company depends absolutely and solely for its gold production on electric transmission; and though a description of this plant would no doubt considerably interest members, I will only here refer to the matter of the driving power. When the scheme was first resolved upon it was a comparatively small affair, and only one turbine—a 30-inch "Victor"—was intended to be used, this driving by ropes on to a countershaft from which the alternators and exciters were driven by belts. Any troubles experienced in the initial stages of working were due entirely to inferior governing, and even now the greatest care has to be taken, as the governors cannot be depended upon to respond with sufficient promptitude to sudden changes of load. At Sheba the 60-stamp mill works continuously day and night, only stopping for a short time every 200 or 300 hours to tighten a rope, take up a belt, or look to the machinery generally. By insisting upon the chargeman signalling from the mine to the power house whenever a change of load is about to take place, our engineer—Mr. John Rance—has got the working into very perfect order; but there was the very greatest difficulty in attaining this perfection. In the early stages they used to drop stamps in rapid succession, which was followed by the motors pulling up, the fuses blowing, the turbine racing, a tremendous increase in the voltage, and general excitement all round. Now they are wiser, and, load changes being signalled beforehand, the man in charge stands by at the generating station and, with one eye on the tachometer and the other on the voltmeter, adjusts the water supply exactly to the requirements. Occasionally, when a stiff piece of rock gets in the crushers, there is a tendency to upset the balance of things, but the achievement of the long runs above mentioned will show that in the working *there* is little fault. At the present moment about 200 horse-

power is being delivered, two turbines being used, but very shortly Mr. Esson. another turbine will be added, and 300 horse-power delivered. It will be obvious that, if we had a governor which could control the turbine speed under sudden variations of load, much less attention would be required to run the plant.

Mr. Steiger, I notice, discredits the very high turbine efficiencies published from time to time, and remarks very truly that the maintenance of a constant power with a constant speed under variation of fall and quantity of water can only be attained by sacrificing efficiency. I would point out that, while it is of the greatest importance to obtain a high efficiency at full load, the efficiency at partial load is generally of minor importance. This has been so in all the schemes which have come under my notice, and I consider good governing of much greater importance for electric work than high efficiency at low loads.

Whether we shall see the water power in this country utilised to a much larger extent by-and-by remains to be seen, but it is certain that with the power at our disposal much more might be done. Whether the local conditions upon which the author rightly lays so much stress will justify a turbine installation when steam plant has to be added to it is a matter for the engineer to weigh carefully, with all the facts before him; and he may even have to decide, if he has option, as to the most economical fall. Only recently an interesting case of the kind came under my notice, where it had to be settled how far up the river the race would be carried. With the lower limit of fall the cost of turbines was a maximum, and the cost of the construction of the race a minimum; with the higher limit exactly the reverse held good. A fall was eventually decided upon which made the cost of the total construction a minimum.

Mr. W. GEIPEL [*communicated*]: I have been anticipated in Mr. Geipel. some of my remarks by Mr. Tremlett Carter, with whose views I generally agree; but there are one or two points in this paper not touched upon to which I desire to refer.

Mr. Steiger recognises the difficulties in utilising low falls due to variations in head and quantity: in the one extreme you have all head and little water, while after heavy rain you may

Mr. Geipel. have abundance of water and little head; and between these two limits you have all degrees depending upon the proverbially variable British weather. Mr. Steiger proposes to meet these difficulties by subdividing the turbine into several compartments. It may be that in some cases this is a good arrangement; but I have some experience in the use of water power for electric lighting purposes, and I find that the varying load on the dynamo adds again to the difficulties of the varying water power. It is also to be remembered that a turbine has a *critical speed*, at which the best efficiency is obtained, and that this critical speed varies with the head of water; whereas, on the other hand, the dynamo requires one constant speed. I am of opinion that it is frequently preferable, therefore, to subdivide your water power and use several turbines, each driving its own dynamo. These turbines should be arranged for working at different heads; one should be for the maximum head, and of suitable size to use only the minimum quantity of water available under that condition. The second turbine should be suitable for a less head and larger quantity of water, the third more so, &c. The number of these units would, of course, be governed by the conditions. An additional advantage of this method is that repairs may be effected to one unit whilst others maintain the supply. I am quite aware that this system may not be economical in all cases, especially where the maximum available power is small; but in many cases it will prove, in my opinion, to give a very much better all-round efficiency than the compound turbines referred to by Mr. Steiger.

There is a more important point only briefly referred to by the author, and which has not been dealt with by any of the speakers, and that is the question of first cost, as to which the author writes: "*The commercial value of a water power depends* "*more on the annual outlay than on the first cost.*" On this point I am directly at variance with the author. I have always thought that the annual outlay on turbines was almost negligible, and that the only other consideration was first cost; if that item be also negligible, why, then, the millennium of those gentlemen who regularly promote, as they do in the public Press, the

utilisation of the tides is verily at hand. It is, unfortunately, this very question of excessive first cost which makes the power produced by low water-falls and tides so much more expensive than in the case of steam or other engines. I think the importance of first cost is being daily driven more closely home to the minds of all electrical engineers, and for that reason it is to be regretted that this paper contains no information whatever upon this important point. Mr. Geipel.

The use of storage batteries for storing the power during periods when the power is not required is well known. I have in several cases found it cheaper to construct a water reservoir, which of course, effects the same purpose.

With regard to the difficulty experienced by the author with round ropes, I think he must have got hold of a very bad quality of round rope. The arrangements of the pulleys are good, and the net strain is only 80 to 83 lbs. per square inch; so that with good English-made round ropes we should have no hesitation in transmitting more than double this power with satisfactory results.

Mr. Steiger, in reply, said: Mr. Carter has stated that the impulse turbines are not suitable for falls, except extremely high ones. He speaks of thousands of feet, and he says that even in a case like Foyers they are not suitable. I most emphatically contradict the statement. An impulse turbine, or action turbine, is suitable anywhere, from a fall of 3 feet upwards to any height—any thousands of feet—where the fall is constant; and they have the advantage that they can be regulated exactly according to the quantity of water, without loss of efficiency. If a miller shuts off the water at night and prevents his neighbour a little lower down working his electric plant, that is not the fault of the power, but entirely the fault of the laws which permit such a thing. You will find in every country where water power is appreciated that the law makes very strong restrictions, preventing anybody from taking away the water from his neighbour during the time that he does not use it. Mr. Steiger.

Mr. Carter: We are not blest with that law in this country. I have gone into the legal point of the question carefully.

Mr. Steiger. Mr Steiger: That is rather an important matter connected with the proper utilisation of water power; and I may say that in Switzerland, for instance, but also in other countries, the law not only protects owners of water power in such cases, but for new plants which are of public utility grants expropriation where necessary; and the local authorities are, in some places, even bound to see that a water power is utilised in the most economical manner. Water power will be much more appreciated in this country when it is really known what can be done in that direction. As regards automatic governors, to which Mr. Carter alludes, these work on low-fall turbines as well as on high-fall turbines; and on the latter the connection of an automatic governor to maintain a regular speed is just as, or more, difficult as in the former, because under a high fall the areas through which the water giving a large amount of power passes is so small that by a trifling movement you can produce a very great variation of power, and sometimes too much, so that the governor might not regulate the speed properly: that is to say, the speed would vary—would go too high, and then the governor would close until the speed is much too low, and then it would open again, and so on. The application of an automatic governor for a high-fall turbine is sometimes an extremely difficult question, but it can be done by properly studying the conditions.*

With regard to the adaptation of turbines to dynamos, or dynamos to turbines, we find it very convenient in the case of the dynamos used in the aluminium works at Neuhausen, and in other cases where large dynamos are used, as in the new works in Geneva, that we can connect them direct with the turbine shaft. If a dynamo requires to run at a certain speed, why should not the turbine be built to run at that speed, if in this manner

* According to the conditions of a water power, and the special requirements, an automatic governor may influence the speed and power of a turbine either by acting on the quantity of water which is allowed to pass through the turbine, or by acting on the fall, or pressure, of the water, or also by reducing or increasing the efficiency of the motor. Any of these methods of applying an automatic governor may be preferable in one case, but very objectionable in another, and the hydraulic engineer alone should decide for each case which of these methods is the most suitable.

expense, power, and space can be saved? or why should not in other cases the dynamo be adapted to suit the speed of a turbine, if by so doing an advantage can be gained? There can be no doubt that the success of many electrical generation plants using water power is due to a co-operation of the electrical engineer and the turbine engineer in this manner. Mr. Steig

Mr. Siemens has alluded to the failure of the turbine plant at Godalming for the electric lighting of the town. That is just a case that suits me very nicely, because it is the best support of my point that a turbine must be carefully selected and judiciously adapted to the local conditions, if good results are to be expected. I do not know what sort of turbine was used there, but certainly it has been proved in more instances than those which I have shown that you can use a water-fall varying from 1 foot to 5 or 6 feet and obtain your power satisfactorily. But, of course, if your fall and quantity of water correspond to a power of, say, 100 H.P., which are available only during, say, nine months of the year, it is useless to put up a dynamo and plant requiring 150 H.P. without the addition of an auxiliary engine. These conditions must be gone into. Just as a given dynamo cannot produce current beyond the limit for which it has been constructed, a turbine cannot give more power than that corresponding to the available fall and quantity of water.*

Mr. Shoolbred has alluded to action turbines on low falls. I am very pleased he has mentioned this, but perhaps he has overlooked that in my paper I said that low falls are very seldom found without variations of the water levels: that is a great difference. If I have water power where the tail water never rises, or where the difference is only a few inches, then I certainly apply an action turbine; but in the case of driving dynamos, where I want to use as high a speed as possible, I would eventually give

* Even if auxiliary power is required, generated by steam or gas or oil engines, it will be economical to utilise the water power as much as possible. Although the first cost will be increased by the outlay for the plant of that auxiliary power, the annual cost will be smaller. These amount to perhaps £2 15s. per horse-power obtained from a *low* water-fall, while they amount to about £8 5s. per horse-power for steam power, assuming 3,000 working hours and 10s. per ton of coal.

Steiger. preference to a reaction turbine—not on account of the inferiority of the action turbine under such conditions, but on account of the higher speed desired, which I can only obtain from the reaction turbine. A reaction turbine I could make smaller in diameter for the same fall than an action turbine, because a reaction turbine is less sensitive to the variations of the angles at the inside and outside of the buckets.

Mr. Mowat has alluded to the plant in India, which is a plant under a rather high fall. They are turbines similar to those at Chauxdefonds; and I think in that plant, with a fall of 200 feet, impulse turbines have been used with satisfaction to the owners. Mr. Shoolbred has also alluded to the water-wheel of Professor Thompson. I have seen that wheel once, but not in actual plant. I believe it is a turbine which gives a good efficiency at full gate. I cannot say how the efficiency is at part gate. I think it is a pity that so few tests are made with turbines in this country and published in order to give reliable information about the respective value of turbines. Some turbines for which very high results are claimed have been tested, and the result of these tests has been very disappointing—that is to say, the efficiency was very much below that which was generally published; and I think anyone who requires a turbine should insist on having a written guarantee that the turbine must give such and such power on such and such a fall, with such and such a quantity of water, stating also the efficiency for abnormal conditions under which the turbine may work for a considerable length of time. I thank you, gentlemen, for the attention which you have given to my paper; and if I can give you any further information later on, I shall be pleased to do so.

In reply to the communication by Mr. W. B. Esson, I would observe that the example of the Sheba Mine plant shows clearly that the requirements of an automatic governor in connection with turbines working an electrical plant are different from ordinary cases. It is evident, therefore, that the ordinary mechanism connecting a governor with the gate of a turbine, working always slowly, cannot be applied in cases where the *variation* of the load is so great. It is, however, satisfactory to

mention that the difficulty of governing in an absolutely satisfactory manner a turbine under the conditions as those mentioned has been solved. The means may differ according to the preponderance of the fall or the quantity of water from which the power is obtained; and if Mr. Esson will furnish me with the necessary details of the fall and the general arrangement, I feel confident that I can submit him a satisfactory solution of the problem. Mr. Steiger.

For the central station at Davos where three 200-H.P. turbines work under a fall of 330 feet, a patent arrangement has been adopted whereby the variation of the speed is kept within 3 or 4 per cent. of the normal speed, even if the whole load were taken off at once. In this case the difficulty is increased by the length of the take-down pipes of about $1\frac{1}{4}$ miles, when any sudden variation of the velocity of the water would put a dangerous strain on the pipes. The same automatic governor which maintains the regular speed acts also on a valve, by which means any excess of strain in the pipes is prevented.

Mr. Esson remarks that a high efficiency at "partial load" is of minor importance. There is a difference between "partial "load" and "part gate." From the economical point of view the efficiency of a turbine should be as high as possible at part gate whatever the load may be, because at full gate the few per cent. efficiency which may be lost when a turbine works at full gate under a reduced head may be compensated by the extra water supply. In most cases it is preferable that an automatic governor should act either by reducing the pressure of the water (under very high falls), or on the quantity of water passing through the turbine, but not on the efficiency by throttling the water, as is sometimes done in connection with reaction turbines.

In reference to Mr. Geipel's communication, I beg to say that the objection which Mr. Alexander Siemens has raised against the utilisation of a varying water power, which would have to be supplemented by steam or other artificial power, would apply with still more reason to the erection of several turbines to utilise the different heads of a varying water power, on account of the capital outlay, which would in such a case be even greater than if a

Mr. Steiger. steam-power plant were put down. Also, from the point of view of efficiency, I consider such an arrangement would have no advantage over the adoption of a Jonval turbine with several rows of buckets. I am aware that the arrangement suggested by Mr. Geipel is sometimes adopted, but rather to utilise a varying water supply by turbines which give a good efficiency only at full gate.

While the good efficiency is in very close connection with the critical speed in the case of "impulse" turbines, this is not so with "reaction" turbines, which alone are suitable for varying heads, as pointed out in my paper, and in which the efficiency is not affected to a considerable extent within certain limits of speed.

As regards rope drives for dynamos, the advantage of the plaited ropes seems to be that they are more flexible, and on this account more durable than round ropes, which would also consume more power.

I should have liked to say something about the cost of water-power plants, but any figures relating to one plant would not apply to another, the conditions varying from place to place. The figures given in the footnote on p. 557 refer to a 50-H.P. low-fall turbine plant in comparison with a 50-H.P. steam-power plant; the annual expense including in each case 5 per cent. interest on capital outlay, 6 per cent. sinking fund, 5 per cent. for repairs and maintenance of the steam plant and 2 per cent. for the water-power plant, besides attendance—£80 for the steam plant, and £4 for the turbine plant, as in the latter no special attendant is required.

I take this opportunity to refer to some points in Mr. Carter's speech which I had left unanswered during the discussion.

By giving the description of some turbine plants which are not used for the generation of electrical energy, and some for high falls, my intention was to show how water power can be rationally utilised under any condition, and to prove by existing and successful plants the necessity of adapting different types of motors to different conditions. There are high falls in British colonies to which British electrical engineers will in time pay *attention*; and, judging from some remarks made in the discussion

Mr. Steiger. regarding the suitability of turbines for high falls, my description of such plants, even if outside the scope of the title of the paper, may tend to correct erroneous opinions on the different types of turbines. It is but too true that water power and turbines have somewhat come into discredit owing to many failures caused by want of judgment and adoption of unsuitable motors, and this may be a justification of my referring also to plants under other conditions than those which are generally found in flat countries.

General Webber. General WEBBER: The hour has passed when I should have been entitled to make the remarks on the paper which occurred to me while hearing it read, and I do not like to take advantage of the opportunity which has been given me by the President thus to supersede those gentlemen who were anxious to speak. But I should like, in asking the meeting to accord a unanimous and hearty vote of thanks to the reader, to remind them that, whatever the criticism may be as to the use of water power in the past, and whatever the opinions—such as those expressed by Mr. Carter—may be, it is a very large and important question, and one for which we ought to be very thankful to a gentleman of the experience of Mr. Steiger in coming to us and giving us a paper which I regard, and which I think the meeting will regard, as an inducement to many of us to go deeper into this question and to study it more. I am in the habit of inspecting water powers of this character—water powers with low fall, and great irregularity in that respect—in various parts of the country; and I think none of us can have failed to call to mind when hearing this paper read instances in which it will be well worth our while to go and investigate the circumstances and see whether we could not utilise the power which Nature has provided at a very small cost. In asking you to return thanks to Mr. Steiger for his paper, I will also ask you to bear in mind that his paper could not have been a full exposition by any means of the subject which he was dealing with, and can only be a suggestive paper, which I have very little doubt many of our members and those present will make use of, and which will be the means of instigating them to turn their attention to this subject in a manner in which they have not done in the past.

Professor Thompson.

Professor SILVANUS P. THOMPSON: I have great pleasure in seconding this vote of thanks. I wish to concur in the remarks of General Webber as to our great indebtedness to Mr. Steiger for his paper. There is one little correction I should like to make to a remark made by one of the speakers. I have recently visited the factory of Menier, where the fall of the river Marne is used; and I found that, on account of the diminution in the height of the fall at the time when floods are coming down the river, they have been compelled to put in, in addition to their turbines, an undershot water-wheel.

The PRESIDENT: I have to announce that the scrutineers report the following candidates to have been duly elected:—

Foreign Member:

Dr. Alvaro de Vilhena.

Members:

A. H. Howard.
A. B. Larkins.
Richard Threlfall.

Associates:

John Henry Alexander.
Gordon Bryant.
Henry Conner.
E. G. Cruise.
Alfred T. Cummins.
Herbert H. B. Deane.
John Gray.
Hugh Hellman.
George Arthur Morton.
George E. Piggott.
Thomas Rungay.
Hubert Russell.
Thomas H. M. Swinburne.
Sydney Weiss.

Students:

Trevor Duesbury.
Herbert Durtnall.
Theodore Arnold Locke.
Robert A. D. Macalister.
Hubert Sadler.
William Steuart.

ABSTRACTS.

THE REGULATION OF PRESSURE AND THE REDUCTION OF LIGHT-LOAD LOSSES IN ALTERNATING-CURRENT SYSTEMS OF ELECTRIC SUPPLY.*

By E. W. Cowan and Alfred Still.

(Abstract of Paper read before the Northern Society of Electrical Engineers, and published by permission of that Society.)

The object of the first part of this paper is to set forth what the authors believe to be the best methods of maintaining constant pressure in all parts of a distribution system under varying conditions of load.

The first point to which attention must be paid is the arrangement of the mains and transformers. There are, perhaps, four systems open for use—

1. High-tension distributors, with transformers on consumers' premises.

2. Feeders in connection with high-tension distributors, and transformers on consumers' premises.

3. Feeders with transformers in sub-stations, and low-pressure distribution.

4. Feeders with transformers in street boxes, and both high- and low-tension distributors.

From the point of view of the regulation of pressure, the first of the above systems is the worst and the last one the best. It is with the relative advantages of the third and fourth systems that this paper mainly deals.

Instead of employing sub-stations with banks of transformers, the authors prefer to space out the transformers under the footway in the manner indicated at D, in Fig. 1. With this arrangement a much better regulation can be obtained than the

* The Editor is indebted to the publisher of the *Electrician* for the blocks illustrating this Abstract.

low-pressure distribution system shown at C. With this system it is simple and inexpensive to lay both high- and low-tension cables of large enough capacity for the ultimate requirements of the district. The transformers, which may be of uniform size, are fixed according to the position and amount of load as it arises; the final result being that the transformers are close together where the load is heavy, and comparatively remote in those positions where the demand is small. The authors prefer to employ 12- to 15-kilowatt transformers, which can have a very high efficiency, whilst being more readily handled than the very large sizes often fixed in sub-stations.

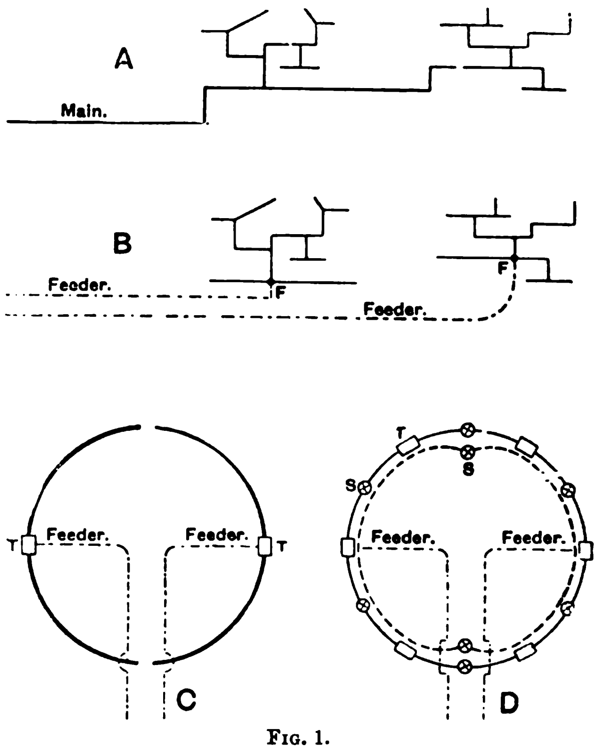

FIG. 1.

If underground switches are arranged to connect the low-tension service mains of one transformer to those of the transformers on each side of it when required, it will be possible to remove a transformer without interfering with the supply. And

if similar switches are fitted at intervals in the high-tension main, a fault in the cable can readily be cut out and the supply continued in the whole district fed by this main, with the exception of the particular length which contains the fault. Such underground switches can be made at a low cost, and will work quite satisfactorily.

The cross sections of the feeders should be proportioned in accordance with Thomson's law; but here a difficulty arises: the loss of pressure will frequently be so great that, at times of full load, uniformity of pressure cannot be maintained at the feeding points, unless all the feeders are of the same length and subject to corresponding fluctuations of load—a condition which does not obtain in practice. It follows, therefore, that a regulating device must be connected to each feeder, preferably at the generating station end, or inequality of pressure at the feeding points will result. The other alternative is to lay feeders which are uneconomical on account of their large cross section and corresponding first cost.

The authors first describe a simple graphic method of determining the sectional area of feeders according to Thomson's law, as the usual formula needs some modification to adapt it to cables of which the insulation bears a large proportion to the total cost, and which do not carry a constant load.

Feeders.—Although Thomson's law, in its usual form, is not directly applicable to existing conditions, the *spirit* of it should never be deliberately neglected. All that has to be attended to, is to see that the annual cost of the energy wasted in a mile of the feeder, added to the annual allowance (per mile) for depreciation and interest on first cost, shall be a minimum. With regard to the question of varying current, the energy lost in a given cable depends upon the square of the current and the time during which the current is flowing. If a cable conveys a current, C, only 12 hours out of the 24 hours, then the energy wasted per day is only half what it would have been had the current been flowing continuously, and the watt-hours may be expressed as $12 \times c^2 \times r$, or as $24 \times \frac{1}{2} c^2 \times r$; and it is evident that in working out the energy lost per annum in the cable, we have to

multiply the resistance, not by the square of the *maximum* current which the cable will carry, but by the mean value of the squares of the current during the year.

From measurements taken on actual load diagrams it would appear that, in the case of electric light supply stations having a small all-day load, the full load or maximum current is from two to three times as great as the mean square value of the current taken for the whole year; this proportion depending upon whether the capacity of the feeder is appreciable or not, and also upon the nature of the districts supplied. It is evident that this multiplier can easily be worked out from a few typical load diagrams.

The following example and the diagram Fig. 2 will make it clear how the proper size of cable may be worked out in actual practice. And, first, it should be understood that it is the cost of the cable only on which the percentage for interest and depreciation should be taken, because the cost of trenching and laying, or drawing into pipes or culverts, will be practically constant, and unaffected by the exact cross section of the copper in the cable. Let us suppose that 10 per cent. is to be allowed for depreciation and interest on capital spent: then, in the diagram Fig. 2, where the horizontal distances represent resistance in ohms, and the vertical distances represent money, plot the curve A, which gives the relation between 10 per cent. of the cost per mile of the cable (taken from the maker's price list) and its resistance in ohms per mile (go and return)—this curve, which has been plotted from actual prices for concentric cables by a certain firm of well-known manufacturers, is not a rectangular hyperbola, as it would be if Thomson's law were to hold good. The dotted curve is a true hyperbola, or the curve which makes the cost universally proportional to the resistance of the cable, and inspection of these two curves will show how the cost of the (insulated) cable is proportionately greater for the smaller sizes.

Now calculate the cost of the C^2 R losses per mile of cable for any particular value of the resistance, and draw the straight line 0 B, which will give us this cost for any other resistance of cable. In this diagram the losses have been calculated on the assumption

that the current is 26 amperes, and that the cost of production is 1½d. per unit. It is evident that this must be taken on the low side, as during the lifetime of the cables the works cost of the unit may be expected to be reduced.

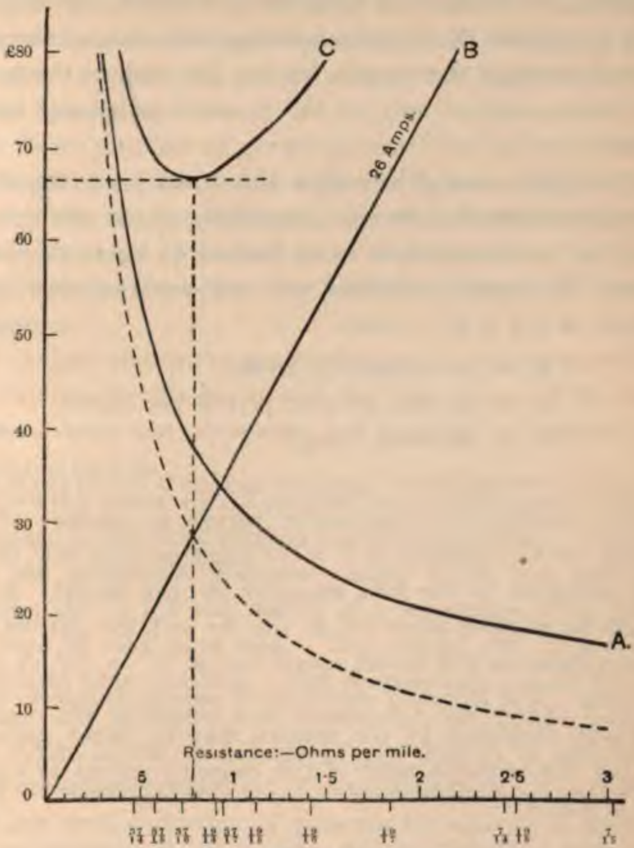

Fig. 2.

By adding the ordinates of the curves A and B, the curve C is obtained, whose minimum value corresponds with a resistance per mile of 0·78 ohm. The nearest cable to this (on the small side) is 19/14, and this, if the cost of production of electrical energy and the probable current have been estimated correctly, is the proper size of cable to use, whatever may be its length or the voltage required at the feeding point.

Assuming the maximum value of the current to be three times the square root of the mean square value, and the length of the feeder to be one mile, the "drop" at full loads would be: $78 \times 0{\cdot}91 = 71$ volts.

Capacity.—The effect of capacity in a system of concentric mains is to increase the current entering the cable at the alternator end, although the current leaving the cable at the far end will, of course, depend only on the pressure and lamp load at that end.

In the long concentric feeders the capacity current should therefore be taken into account, especially as its effect in increasing the total current is more marked at light load than at full load. It is easily calculated with sufficient accuracy by the formula, $C = 2\, \pi\, n\, K\, V$, where

K = the capacity in farads,
n = the frequency in periods per second,
V = the mean voltage.

It must be remembered that this current is not in phase with the main current, but one-quarter period in advance of the impressed volts. Hence, if $C = 10$ amperes, this will be the current indicated by the feed ammeter on open circuit. At full load, with 60 amperes taken out at the far end, the current read on station ammeter will be the square root of $60^2 + 10^2$, or about 61 amperes. The following capacities of concentric cables, which were kindly furnished by the makers, may be found useful in estimating the probable value of the capacity current in a given system of mains:—

Capacities per mile (inner to outer) of 19/18 concentric cables:

British Insulated Wire Company (paper) ...	...0·31	microfarads.
Glover & Co. (vulcanised rubber) ...	...0·615	„
„ (diatrine)	...0·315	„

Drop on Feeders.—Having fixed the cross section of the feeders and calculated the full-load "drop," it will generally be found that the latter is considerable on the long feeders and inappreciable on the short. Some methods of dealing with this difficulty must, therefore, be adopted which will allow of each

feeder being independently regulated, as, if the pressure of the 'bus bars be raised to compensate for the drop on the long or heavily loaded feeders, the pressure at the feeding points which are nearer the generating station, or at those which are more lightly loaded, will be increased at the same time. There are three methods of effecting the desired result, all equally efficient in respect to regulation, but differing widely in their efficiency in respect to economy—

1. Raise pressure of generators until 'bus-bar pressure equals that required for the feeder with the largest drop, and switch more or less resistance into all the other feeders to absorb the consequent excess of pressure above that required.

2. Same as above, but use variable choking coils instead of resistances.

3. Adjust pressure of generators until 'bus-bar pressure equals that required for the feeder with the least drop, and by means of a special induction apparatus add pressure as required to the remaining feeders.

Very few words will be required to show the great economical advantage of the third method over the two others. In the first plan the resistances dissipate energy which has cost fuel to produce, and so rob the station of a percentage of its output at the time of maximum load. The second plan is much more economical than the first. But choking coils are not like transformers—the induction, and consequent loss in the iron, being very much higher on account of the E.M.F. of self-induction being one-quarter period out of phase with the main current. For a 10 per cent. reduction of pressure the amount of the induced volts will be over four times the volts deducted. But, apart from this, it will be readily seen that the generation of the E.M.F. by the dynamo, and its subsequent destruction by the choking coils, cannot be an economical arrangement, accompanied as it must be by the losses of a double operation. The third plan is free from the above objections: the volts required to compensate for drop are added when and where required, and the generators, being worked at a low pressure, work more economically.

As far as the authors have been able to ascertain, the late

Mr. J. E. H. Gordon was the first to make use of the idea of augmenting the E.M.F. of a circuit by connecting in series with it the secondary coil of a shunt transformer. In Fig. 3 this plan is illustrated. Part II. on the same diagram shows a feeder-regulator designed by Mr. Gisbert Kapp. A segment switch is arranged to cut out the primary coils as desired; as the coils are

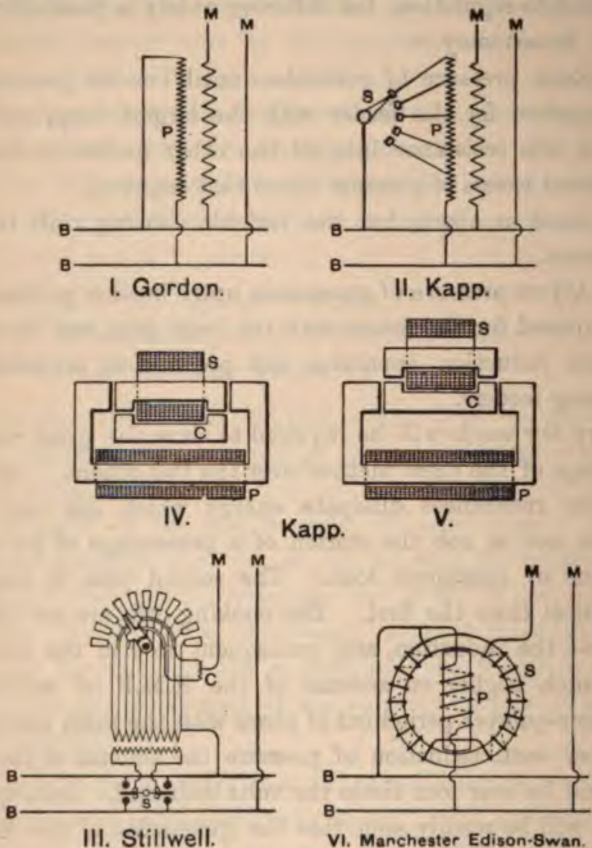

FIG. 3.

cut out the E.M.F. generated in the secondary is, of course, increased. Part III. shows the principle of an apparatus designed by Stillwell, in America, and manufactured by the Westinghouse Company. This design is similar to Kapp's, and was, indeed, also suggested by him, the only difference being that, instead of primary coils being cut out, secondary coils are switched in.

IV. and V. illustrate another design of Mr. Kapp's, which was intended to get over the difficulties of a high-tension segment switch, with its necessary devices to avoid short-circuiting a coil when being moved from one segment to another, and also to get over the objection of the additions to the voltage taking place in jumps. The principle of its action is entirely different to the others, the variation in effect being obtained by a movement of the iron core. IV. shows the apparatus in the position of maximum effect, the magnetism created by the primary coil cutting the secondary coil. In V. the core and secondary coil are removed to the position of no effect, the magnetic lines flowing along the core C, outside the secondary winding instead of through it.

Part VI. of Fig. 3, Fig. 4, and Fig. 4A illustrate the regulating transformer manufactured by the Manchester Edison-Swan Company, Limited, as first made for the Bolton Corporation. In this design the primary coil is wound upon a shuttle-shaped core, and the secondary winding upon a ring-shaped core. Between the positions of maximum effect and no effect the primary coil, with its core, rotates through an angle of 90 degrees. The action is as follows:—In the position of maximum effect the shuttle occupies a vertical position, and the magnetic flux cuts the secondary coil, which is wound in two sections, one on each side of the ring, and generates the full volts required. In the position of no effect the shuttle is horizontal, and the magnetism cuts half the secondary turns in a positive sense and half in a negative sense, the resultant effect being, of course, *nil*. Between these two positions any gradation of augmentation can be obtained. It is evident that if the shuttle be rotated beyond the position of no effect (if the transformer is being used as a feeder-regulator) volts will be subtracted from, instead of added to, the feeder volts. The points to which special attention were paid in the design of this apparatus were the constancy of magnetic flux in all positions, the reduction of the iron path to the shortest possible length to avoid iron loss, and the obtaining of a mechanical and

compact apparatus which would lend itself to easy and safe manipulation by the switch-board attendant.

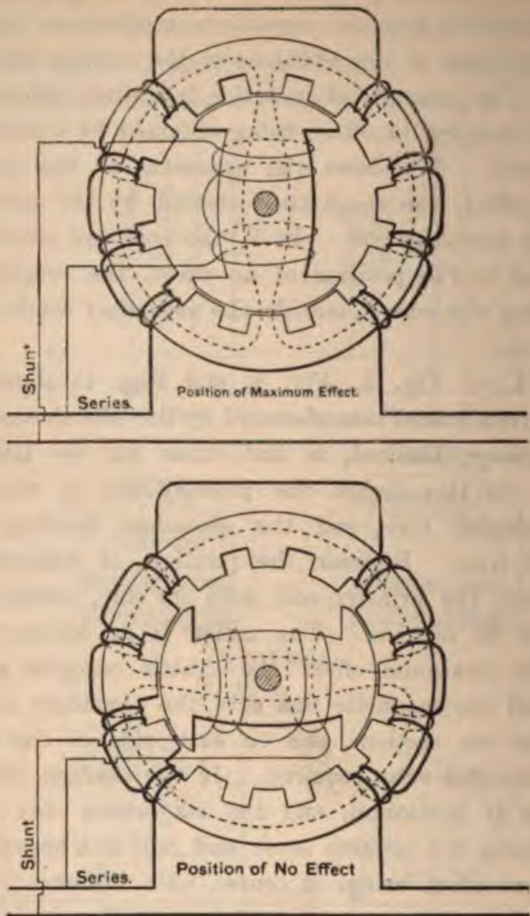

FIG. 4.

Compensators.—For indicating the feeding point volts at the station end, pilot wires may be brought back from the feeding points to the voltmeters; but the principal objection to their use is their excessive cost, especially when they are used in connection with long feeders. A very simple method of indicating the pressure required at the station end of the feeders, in order that the supply at the far end may be independent of variation in load,

consists in marking on the feeder-ammeters a second scale of numbers—say in red figures—these numbers indicating the required value of the station volts for any position of the ammeter needle.

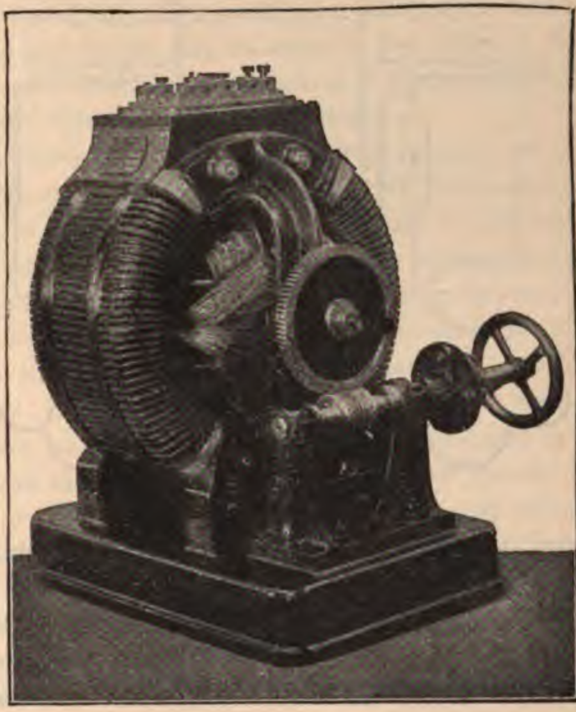

FIG. 4A.

A step in advance of this, is a method which is more generally used in America than in this country. It consists in connecting the voltmeter in series with the secondaries of two transformers—a shunt transformer, T_1 (A, Fig. 5), with its primary across the mains, and a series transformer, T_2, of which the primary is traversed by the main current. The secondary of this transformer being closed through an adjustable resistance, R, it will be readily seen that, by suitably varying this resistance to suit the length and size of the feeder, the potential difference between the terminals, t t, may be adjusted to any particular fraction of the

volts lost in the feeder. It follows that, by setting this potential difference against the potential difference at the secondary terminals of the shunt transformer, the readings on the voltmeter will be an indication of the actual pressure at the feeding point.

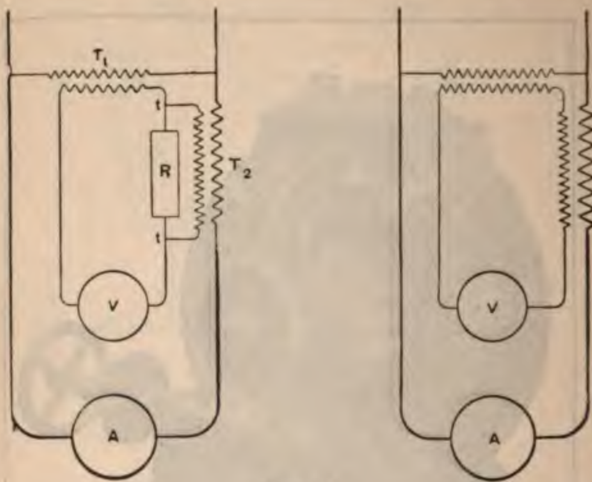

FIG. 5.

In B on the same diagram is shown the way in which this method of "compounding" the feeder voltmeter is illustrated in Dr. J. A. Fleming's book on transformers. In the text we read that "the "electro-motive forces of the two transformers are opposed to one "another;" but this will not be the case unless the secondary of the series transformer is closed through a resistance, as in A. The secondary volts of the shunt transformer being in opposite phase to the primary volts, and the induced volts in the series transformer being approximately one-quarter period behind the main current, these two E.M.F.'s cannot be set *against* one another, and their sum must necessarily be *greater* than the value of any one of them.

Drop in Distributors, &c.—So far, only the loss of pressure in the feeders, and methods of keeping the volts constant at the feeding points, have been dealt with. Beyond this the system must be self-regulating; that is to say, the loss in pressure between no load and full load must not exceed a certain definite

amount. The amount of permissible variation at the consumer's terminals, as fixed by the Board of Trade, is 4 per cent. If, therefore, the distributors be proportioned so as to give a maximum drop not exceeding 2 per cent., this leaves another 2 per cent. for permissible drop in transformers. It should always be borne in mind, in specifying for transformers, that for the same cost of material a transformer may be made to give either a small drop with a comparatively large iron loss, or a fairly considerable drop with greatly reduced open-circuit losses.

As an illustration in actual practice which bears out this statement, the authors, a few months ago, tested a transformer for which the makers claimed an unusually small loss at light loads. The tests proved that the claim was undoubtedly well justified; but the drop on volts on secondary terminals between no load and full load was no less than 5 per cent. On the other hand, a transformer of the same output, by another maker, had an open-circuit loss nearly 1½ times as great, and this although the weight of the transformer, and, therefore, the amount of material in it, was greater than the first one; but this greater iron loss was necessary in order to bring the drop within reasonable limits, the maximum variation being just within 2 per cent. In very small transformers it is difficult to keep the drop much below 2½ per cent.; a better regulation than this is rarely found in practice.

With regard to the drop of pressure in the house wiring, it should be borne in mind, in calculating sizes of wires, that their effective resistance to alternating currents is always a little greater than when they are traversed by a continuous current. Mr. E. Hospitalier has worked out a very convenient table, which will be found reproduced in the *Electrician* of January 12th, 1894, and from which the increased resistance of wires to alternating currents for various diameters and frequencies may be easily obtained; this increased resistance is practically negligible except for wires, say, over ½ inch in diameter, and comparatively high frequencies.

A small regulating transformer connected in series with the low-tension wires entering the houses may also be used for keeping the pressure constant within a fraction of a volt, notwithstanding variations in the supply at the consumer's terminals.

Reduction of Light-Load Losses.

The maintenance of a continuous supply cannot be avoided, although the cost of generation during the hours of light load is enormous. The waste is not only in fuel, but in wages and capital. An examination of the question shows that there are, perhaps, four ways of meeting the difficulty—

1. Installing accumulators which are charged during the hours of heavy load, and employed during the hours of light load in driving a motor alternator.
2. By running a small, and, therefore, more economical, light-load plant.
3. By a gas engine and gas generator plant.
4. By adapting one of the smaller units in the station to work at a relatively high economy when lightly loaded.

Below, these four methods are briefly dealt with.

Installing Accumulators.—The question of the adaptability of accumulators to alternate-current stations in conjunction with a motor alternator to effect economy, is a difficult one to decide. It is a question of interest on capital outlay, depreciation, and maintenance on the one hand, against saving in fuel and wages, and also the undoubted advantage of being able at times to shut down the steam plant entirely, on the other.

Separate Light-Load Plant.—One objection to this is its first cost, and another the frequent necessity for changing over from one plant to another, which, as it involves paralleling, needs the presence of a skilled attendant. This is felt most in the early morning in winter time, when the load is relatively heavy for an hour or two, and a small plant cannot meet the demand.

Gas Engine and Gas-Generating Plant.—At first sight a gas engine appears particularly fitted for this purpose, as it is theoretically an engine with a high efficiency at light load, on account of the gas consumed being proportional to the indicated horse-power. But there is another factor which influences the gas consumption, viz., the friction of the engine. In order to adapt a gas engine to driving an alternator it must have two or more

cylinders and a heavy fly-wheel, the consequence being that the standing friction losses are largely increased, thus seriously affecting the economy at light loads. The first cost of such a plant is, of course, much higher than that of a steam engine of similar power.

Adapting one of the smaller Units in the Station to work at relatively High Economy when Lightly Loaded.—The authors recommend this plan as being the most effective and economical.

Boilers.—As regards boilers, they call attention to the fact that a Lancashire boiler, at any rate, works at a much higher economy at quarter load than at full load, if it is well lagged and carefully stoked. A boiler cannot have too much heating surface, though it can have too much grate area. With careful stoking, a consumption of 5 lbs. of fuel per square foot of grate area per hour in a Lancashire boiler will give a splendid evaporative performance of over 12 lbs. of steam from and at 212° F. per pound of coal, or 10 per cent. better than with a normal consumption of 20 lbs. of coal per square foot of grate per hour.

Economiser.—Although it might be thought that an economiser would not effect much saving at light loads on account of the lower temperature of the gases, the authors have obtained an augmentation of temperature of the feed of 138° F. with a 96-tube Green economiser, when working a Lancashire boiler 30 feet by 7 feet at quarter load, and burning 5 lbs. of fuel per square foot of grate per hour. Professor Kennedy has obtained an evaporation of 12·4 lbs. of water per pound of fuel with economiser, and 11·7 without, when burning only 6 lbs. of fuel per square foot of grate per hour.

Boiler Feed.—In this matter, the authors recommend the use of injectors in cases where the feed water is not heated above 150° F. As a safeguard, they advise the erection of a steam pump as a stand-by; and, in order to overcome the difficulties caused by the small range of injectors, they fix three or four different sized injectors to deliver in parallel into a common delivery pipe—an arrangement which enables any required rate of feed to be obtained, and works well in practice. They consider that the thermal

efficiency is practically the same as that of a feed-pump system in which no economiser is used.

Steam Pipes.—There are grave objections to supplying the light-load plant with steam from the main steam pipe. This plant should be erected as close as possible to the boilers, and supplied by a short auxiliary pipe of small diameter. It has been estimated that the radiated heat from every square foot of lagged steam pipe costs 300 lbs. of coal per annum; and Professor Kennedy has found that the amount of condensed steam from pipes, drains, &c., amounted in one station to from 8 to 9 per cent., and in another from 5 to 6 per cent. of the total weight of feed water.

Auxiliaries.—The authors prefer to arrange for the economiser scrapers, centrifugal pump, and exciting dynamo being driven by the main day-load engine, using either belt, rope, or electrical transmission. As this engine is running in any case, its standing losses are not chargeable against the small extra power required, which can therefore be obtained at the very small expenditure of steam of about 12 lbs. per horse-power.

Condensers.—The authors unhesitatingly recommend the ejector condenser as being the most economical light-load type. No air pump is needed, and thereby a substantial standing loss avoided. It is an absolutely reliable, cheap, and efficient piece of apparatus. The type with a means of regulating the adjustment of the nozzles is perhaps best suited to a variable load. The subject of the saving effected at light load by the removal of the standing loss of atmospheric back pressure by condensing the exhaust steam, has been very ably and fully dealt with by Mr. Willans, and the authors state that it is the most important of the means which they bring forward for the reduction of light-load losses. Fig. 6 shows the saving of steam effected during the day-time at Altrincham by the use of an ejector condenser. The diagram shows the indicated horse-power below and the indicated horse-power above the atmospheric line on the morning of December 20th, 1895. The indicated horse-power below the atmospheric line amounted to about 46 per cent. of the whole, or a saving of steam consumption of about 50 per cent., against which must be set the horse-power required for centrifrugal

pump—about 1 per cent. of the total horse-power of the engine.

Engine.—A steam engine runs very wastefully at light load, partly on account of its standing losses being practically constant at all loads, and therefore bearing a larger proportion to the power developed at light load than at full load, and partly on account of

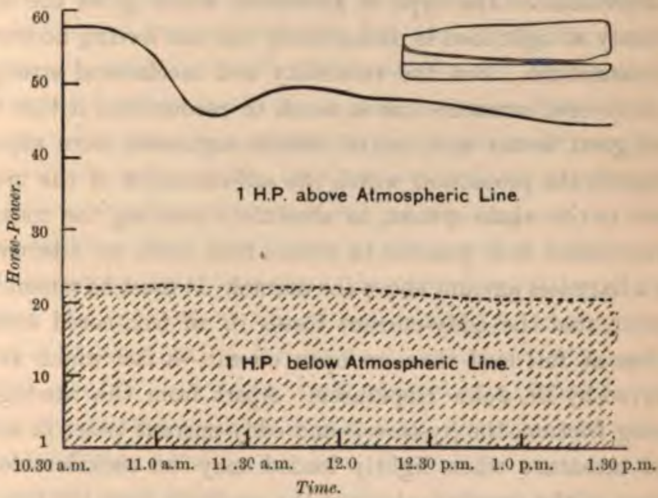

FIG. 6.

the steam distribution between the high-pressure and low-pressure cylinders being unequal at light loads. The latter point should be dealt with by designing the engine with an automatic cut-off governor, which acts on both the high-pressure and the low-pressure valves. In this way a fairly equal range of temperature in the two cylinders can be maintained at all loads. The cylinders should also be steam-jacketed, on account of the range of expansion being relatively great at light loads. Of the standing losses, the back pressure of the exhaust has already been dealt with, and the loss due to radiation can only be met by careful lagging of the cylinders and their covers. Lastly, there are the important losses due to engine friction and vibration. The only way of reducing these is by lowering the engine speed. These losses are so much per revolution, and if we lower the speed we reduce them in like proportion. The authors recommend that

the speed should be reduced by about one-third, and that the governor should be so designed as to allow of an adjustment of its springs being made by hand, in order that the engine may be under its control at this reduced speed. As far as the engine is concerned, there can be no doubt of the advantage of this plan; its effect on the electrical plant is dealt with below.

Alternator.—The type of alternator which gives the highest efficiency at light load is undoubtedly the one having no iron core in its armature. But the reliability and mechanical strength of the iron-cored armature has so much to recommend it that it has found great favour with central station engineers, more especially as regards the protection which the self-induction of the machine affords to the whole system, in absolutely limiting the maximum current which it is possible to obtain from such an alternator to only a harmless amount above the normal. It must be remembered, however, that the eddy-current losses in an iron-cored armature are less at full load than on open circuit—a fact which was first observed by Dr. John Hopkinson. Apart from the windage and bearing friction, the hysteresis and eddy-current losses in an iron-cored armature when lightly loaded may be considerable. On account of the peculiar raking of the magnetic lines, the iron losses in an armature, for any particular values of the induction and frequency, are greater than they would be if the same volume of iron were simply submitted to reversals of magnetism, as in a transformer. The core losses in an alternator will increase approximately as the square of the induction; if, therefore, we could reduce the induction in the armature, a great saving of the all-day losses would be effected. For instance, suppose the armature to consist (as it often does) of two separate windings connected in parallel: by switching these in series during the hours of light load the induction in the core would be halved, and the iron losses consequently reduced to one-quarter of their former value; the losses in the exciting circuit being also reduced in the same proportion. Such an arrangement could not be worked without causing fluctuations in the light; but a little consideration will show that the same saving may be effected by the use of a step-up transformer. The alternator is excited to give,

say, half its normal voltage, and its armature is connected in series with a transformer wound to add the remaining half of the required volts. The loss in such a transformer will be very small compared with the saving in the alternator. All that now remains to be done is to make this transformer a regulating one, which will enable the volts added to be varied without any sudden fluctuations. The change of the alternator from a small-output machine to one capable of dealing with the full load it was designed for can also be made without any variation in the light, by simultaneously reducing the volts added by the step-up transformer, and increasing the excitation of the alternator, as well as bringing up its speed, if this has been reduced as recommended when dealing with the question of engine efficiency.

The capital outlay on such an apparatus would not in any case amount to much; but where regulating transformers are used for equalising the pressure at the various feeding points, as recommended in the first part of the paper, they can be, without any difficulty, adapted to do duty both as regulators of pressure and step-up transformers. The secondary must be wound with several separate windings, which, by means of a special switch, can be connected either in series or in parallel. By means of a simple interlocking device this switch may be so arranged that it can only be thrown over at a time when the transformer is in the position of no effect.

In Fig. 7 are plotted the results of some experiments which the authors made on an iron-cored alternator in order to prove what has just been said with regard to the saving of alternator losses. The alternator was driven at constant speed on open circuit by means of a small continuous-current motor, and readings were taken of the power supplied to the motor for various inductions in the armature. In the diagram the vertical distances are proportional to the volts as read on an electrostatic voltmeter, and the horizontal distances are proportional to the power supplied to the motor, a correction being applied for the losses in the motor itself. The distance $O\ O_1$ represents the losses in windage and bearing friction; it is the power required to drive the alternator with the field magnets unexcited. The curve $O_1\ A$ is a

parabola, the distance of any point on the curve from the vertical line O_1 D being proportional to the square of its height above the horizontal datum line. The points enclosed by the small circles are the results of the experiments, and by their agreement with the curve O_1 A serve to show that, in assuming the iron losses in the armature to be proportional to the square of the induction, the

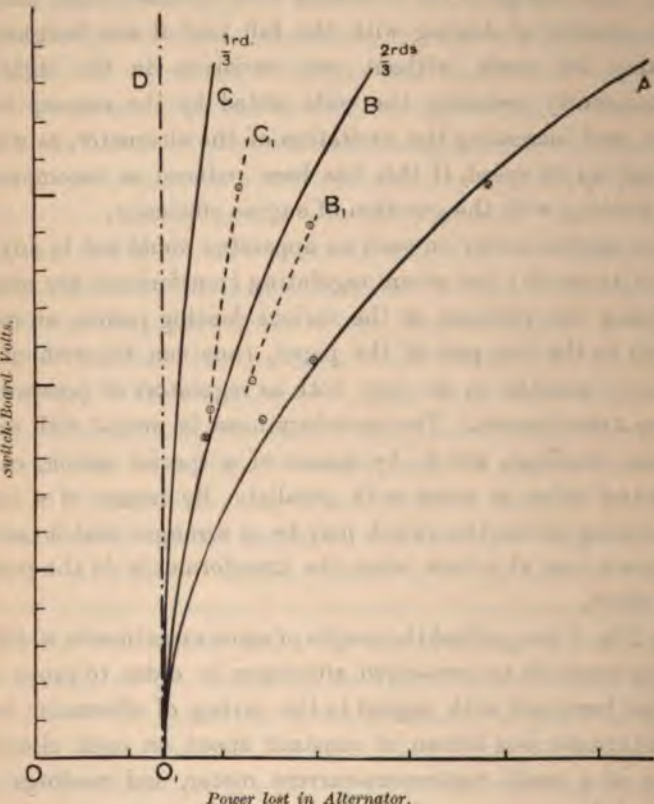

FIG. 7.

error—if any—is very small. The curves O_1 B and O_1 C are also parabolas, but for equal ordinates the horizontal distances from the line O_1 D are respectively four-ninths and one-ninth of their value for corresponding points on the curve O_1 A. These are the curves which would be obtained by connecting the secondaries of the step-up transformers in series with the armature circuit, on the

assumption that the losses in the transformers themselves are negligible. In the case of curve B the alternator generates two-thirds of the full volts, and the step-up transformer supplies the remaining one-third. Two experimental readings were taken through which the curve B_1 has been drawn. These readings, of course, include the losses in the transformer. The dotted curve C_1 was obtained when the alternator generated only one-third of the total volts. In this case, as will be seen by inspection of the diagram, the step-up transformer absorbed rather more power than in the previous experiment. Indicator diagrams of the horse-power of the engine showed the same saving.

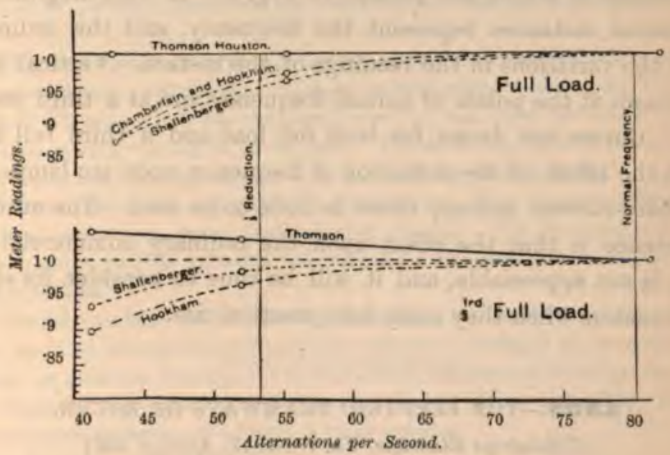

FIG. 8.

In conclusion, the effects of the alteration of frequency which result from the reduction of speed by one-third, must be dealt with. In the first place, the hysteresis losses in the transformers are increased by about 25 per cent., while the eddy-current losses remain approximately the same. As the $C^2 R$ losses are small when the load is light, the resulting temperature will not be abnormally high. The question therefore naturally arises as to whether the saving in the engine is not made up for by the increased losses in the transformers. The best answer to this question is to give the result of a careful experiment made at Altrincham. In this experiment the speed of the engine was reduced from 350 to 246,

and the saving in the indicated horse-power was 16·1 per cent., which is equivalent to a saving of 17 per cent. with a reduction of speed to two-thirds full speed. It must also be remembered that at Altrincham the transformers are for the most part fixed on consumers' premises, and are therefore of small size. Under ordinary circumstances with large transformers the saving should be at least 20 per cent. The effect of the alteration of frequency upon the meters is not serious. If Thomson meters are used the error for a third reduction is practically negligible. With Shallenberger and Hookham meters it amounts to from 1½ to 5 per cent. The authors have made experiments on these meters, the results of which are plotted in Fig. 8. In this diagram the horizontal distances represent the frequency, and the ordinates show the variations in the readings of the meters. Vertical lines are drawn at the points of normal frequency and at a third reduction. Curves are drawn for both full load and a third full load. As to the effect of the reduction of frequency upon arc lamps and alternate-current motors, there is little to be said. The authors' experience is that the effect upon the ordinary commercial arc lamp is not appreciable, and it will be time to consider its effect upon motors when they come into practical use.

ANON.—THE ELECTRIC TRAMWAYS OF ROUEN.

(*L'Éclairage Électrique, Vol.* 7, *No.* 17, *April, p.* 168.)

The inauguration of the Rouen tramways, which operate on the Thomson-Houston system, took place in March. The system is divided into two groups—the one which was previously worked by horse traction, consisting of eight lines having a total length of 25,460 metres; and the new one, consisting of eight lines having a length of 11,607 metres.

The rails weigh 44 kilogrammes per metre, and are of the Broca type, with a gauge of 1·44 m. There are many curves, which, in some cases, have a radius as small as 20 metres. The maximum slopes amount to 4·5 to 5 centimetres per metre. The rails are connected together by "Chicago rail-bonds," and also by means of a double copper wire 8 mm. diameter. At short distances along the track the two parallel rails are connected together in a similar manner.

The overhead trolley wire is of copper, 8·25 mm. in diameter. This wire is suspended over the centre of the track by means of steel strain wires fixed to metallic posts. The steel strain wires are insulated both from the trolley wire and from the posts in such a manner that a leakage to earth is impossible. The 1,200

posts are of steel in four sections, and stand at a height of 7 metres from the ground. Some of these posts carry arc lamps or incandescent lamps, and it is probable that before long all the tramway lines will be illuminated by electric light.

The feeders employed for the overhead line are of 200 sq. mm. section. They are substantially rubber covered, and laid directly in the earth.

The cars have a double platform; they are divided into two classes, and are capable of carrying 24 passengers inside and 16 on the platforms. The weight of the car when full is 7 tons, and the total length 8 metres. The trucks are of a new type, and are both light and strong, the parts being easily replaced. The trolley wheel is of bronze, and is fixed to a trolley bar of a new type, which possesses the advantage of being in a vertical position when out of use, and can be inclined either forwards or backwards. The series-parallel, K^2 type of regulator is employed, differing from those in use at Havre by having an additional resistance for easing the starting. The latter consists of metallic strips mounted on porcelain insulators and contained in a cast-iron frame placed in the car.

The fuses consist of a strip of fusible alloy placed between the poles of a magnet for blowing out the arc. Each car is fitted with two slow-speed motors of the G.E. 800 type, which are completely boxed in, and drive the axle by single-reduction gearing running in an oil bath. The motors are of 25 H.P., and weigh 660 kilogrammes; they are supported on the truck by rubber buffers.

The generating station is situated near the Seine. It at present contains three dynamos, rope-driven from Corliss-Farcot engines. The dynamos are over-compounded to give 200 kilowatts, 550 volts, 425 revolutions per minute, and 500 volts at no load.

The engines have single cylinders, and run at 70 revolutions per minute. They are fitted with fly-wheels 7 metres in diameter. Owing to an increase in the number of cars, the dynamos will be replaced by machines of 300 kilowatts.

There are at present three boilers of the Babcock-Wilcox type, with a heating surface of 160 sq. mm., and a fourth is being installed.

A Green economiser is used.

The condenser water is pumped into a Sée refrigerator by an electrically driven pump. The switch-board consists of three panels for the dynamos and three for the feeders. The panels are of varnished slate mounted in iron frames.

D. BUNGETZIANO—THE DIFFRACTION OF THE "x" RAYS.

(*L'Éclairage Électrique, Vol.* 7, *No.* 17, *April, p.* 165.)

Photographs taken by the author show that the phenomenon of interference by diffraction can take place in the case of the x rays.

The author's attention was first drawn to the pecularities of photographs taken when the x rays were made to pass through the tube of a funnel. The first photograph was obtained in the following manner:—Within the tube of the funnel was fixed, by means of a cork, a small glass tube, the lower end of which

was at a distance of about 4 cm. from the photographic plate; the latter being enclosed in a dark box. An exposure of 25 minutes was given.

On the photograph it was observed that in the centre of the large white spot corresponding to the aperture of the funnel there appeared a shadow of the extremity of the glass tube, this shadow being surrounded by two circular fringes due to the diffraction of the invisible rays. The second photograph shows the phenomenon of diffraction, produced by a circular hole 3 mm. diameter, made in a metallic plate placed at a distance of about 6 cm. below the tube and 10 cm. above the plate. The photograph shows well-defined interference fringes. Also on each side of the central point there is an indication of the formation of two other luminous points, and it is round one of these that the best interference circle is observed.

This peculiarity would confirm the hypothesis of the existence of several centres of emission of the x rays. As would also the results obtained with a slit 2 mm. wide made in a metallic plate.

The author considers these results of importance as concerning the hypothesis of the propagation of these rays by flux or molecular bombardment, and also with regard to the periodicity of these rays. These results may also lead to the possibility of measuring the wave-length of this system of vibrations.

ANON.—DR. JACQUES'S METHOD OF OBTAINING ELECTRICITY DIRECT FROM CARBON.

(*L'Éclairage Électrique, Vol.* 7, *No.* 17, *April, p.* 172.)

The above method consists in oxidising carbon, or other material rich in carbon, in the presence of an electrolyte; the chemical energy of combination being then transformed into electrical energy, instead of being transformed into heat energy. The electrolyte employed is a concentrated solution of caustic soda.

The carbon dips into the caustic soda solution, and air is pumped uniformly through the electrolyte. The iron vessel containing the electrolyte forms the positive pole, and the carbon the negative pole. The whole is placed in a furnace, and is maintained at a temperature of 400° to 500° C.

Under these conditions, the carbon is gradually converted into carbonic anhydride, which escapes in bubbles; the composition of the sodium hydrate is not altered; the nitrogen also escapes with the carbonic gas. A small quantity of the latter gas, however, combines with a portion of the caustic soda and forms carbonate of sodium, which, mixing with the ashes of the carbon, contaminates the electrolyte and decreases its effect. An arrangement of pipes is consequently employed to renew the solution. The properties of the electrolyte can be improved and its life increased by the addition of a small quantity of oxide of magnesium. According to Dr. Jacques, the free carbonic anhydride combines in preference with this oxide than with the caustic soda, and the carbonate of magnesium thus formed is then decomposed into carbonic gas, which escapes, and into magnesium oxide, which is then capable of recommencing its action. It appears that the current obtained from this cell is fairly strong, but that the electro-motive force is very weak.

L. LORTET—THE INFLUENCE OF INDUCED CURRENTS ON THE ORIENTATION OF LIVE BACTERIA.

(L'Éclairage Électrique, Vol. 122, *No.* 16, *April, p.* 892.)

Live bacteria are found to be very sensitive to the influence of induced currents, and immediately place themselves in the direction of the current. They are, however, not influenced by the current, when killed or rendered motionless by the action of an antiseptic liquid.

To perform these experiments, a large sheet of glass was used, in which four deep grooves were filed at right angles to one another, and in which platinum wires were cemented. These wires did not meet in the centre, but left a space occupied by the liquid containing the bacilli, this being prevented from evaporating by being covered with a thin sheet of glass. By this arrangement it was possible to rapidly reverse the direction of the current, which was obtained from a Ruhmkorff coil about 12 cm. long, worked from a single bichromate cell. The moment the current is started the numbers of bacilli visible in the field of the microscope, arrange themselves parallel to the direction of the current, and remain stationary, with a weakened vibratory movement. If the current be altered to a direction at right angles to the above, the bacteria rapidly arrange themselves in the direction of the new current; they, however, do not touch one another end to end as polarised bodies should do, but merely place themselves parallel to one another and to the current. After being submitted for nearly 12 hours to the effect of a strong current, the bacteria (*Bacillus subtilus* and similar forms) appear in no way affected, and resume their normal condition immediately the current is stopped.

When old, or placed in contact with a substance which kills them, the bacteria are no longer influenced by the current.

If in the liquid is placed a drop of carbolic fuchsine, this will dye and destroy the bacteria; and they will then remain motionless under the influence of the current. This is, however, not the case in the zone where the colouring matter has not penetrated. Constant currents have no effect on these micro-organisms.

In 1867 the author published the fact that the "spermaties" of mushrooms and lichens, when alive, behave in the above manner. Researches made, in Germany, have shown that these "spermaties" are merely the parasitic bacteria of certain inferior vegetables.

The author concludes, from numerous experiments, that live bacteria are the only organisms which possess the property of orientation under the action of induced currents. This property is not merely physical, but indirectly related to the vitality of the protoplasma.

A. RIGHI—NEW EXPERIMENTS ON THE GLOBULAR SPARK.

(L'Éclairage Électrique, Vol. 6, *No.* 10, *March, p.* 457, *No.* 11, *p.* 495, *No.* 13, *p.* 590.)

(Continuation from last Number.)

In these experiments the author finds that different types of sparks are obtained by altering the distance between the balls of the exciter. When this distance has

become great enough, the globular spark is observed; and on still further increasing this distance the compound discharge is obtained, consisting of a series of globular sparks.

By repeating the series of experiments with different resistances in circuit, or with different pressures of gas, the results remain practically the same, but the luminous masses have different shapes, dimensions, and velocities.

These phenomena are largely influenced by the order in which the instruments are placed relatively to one another in circuit.

It is found that, in order to obtain the globular discharge and to prevent the stratified discharge, the tube must be placed between the exciter and the water resistance.

The globular discharge commences to appear, when the pressure is gradually increased, and some time after all phenomena of stratification have ceased. A long series of experiments have been made with gradually increasing pressures, and with a number of different gases, and in all cases has been noticed a distinct stage between the phenomena of stratification and the formation of the globular spark. There is, however, a continuity between the stratified discharge and the spark discharge.

Photographs of these discharges have been obtained. The distance through which the luminous mass travels, depends on the pressure of the gas, and increases with it. The relative distance between the electrodes has no influence. If, however, the electrodes be brought too near together, the discharge cannot free itself, and the phenomenon is then changed into a progressive spark. Under some conditions the effect has remained visible for as long as 10 seconds, and sometimes longer, and a return motion towards the positive electrode has been noticed before its final disappearance.

By successively interrupting the condenser circuit, a corresponding number of luminous masses are produced. The photographs clearly show how the volume of the luminous mass increases, and how its brilliancy decreases with a decrease in the pressure of the gas.

These phenomena are materially influenced by the dimensions of the tube.

As a general rule, with tubes which are very long, relatively to their diameter, the discharge tends to be a compound one.

On reversing the connections the luminous masses move a little more rapidly, but remain longer stationary before disappearing. In some cases it is found that the fact of reversing the connections alters a simple discharge to a compound discharge. If, instead of allowing the condenser to discharge spontaneously, a prolonged discharge is produced, with a sufficiently high battery potential, then under these conditions a compound discharge is formed, accompanied by characteristic effects.

By placing the discharge tube in an oil bath, in order to vary its temperature, it was found, all things being equal, that the number of luminous masses constituting the discharge increase with the temperature. The discharge is best formed in nitrogen, in which case the discharge is very brilliant and moves slowly. Among the many gases and vapours experimented with, there are few in which the phenomenon could be produced. The following gases are mentioned in the

order with which the discharge is formed with difficulty. Carbonic oxide comes directly after nitrogen. The discharge is less brilliant, and is of a greenish colour, and its movement is more rapid. The fact that these two gases have almost identical molecular weights and critical constants, may lead to a theory of the globular spark.

The other gases producing this phenomenon do so in a far less marked manner, and only within certain limits of pressure.

In the case of hydrogen, the flame is of a pale bluish white colour of a long shape, and moving much more rapidly than in nitrogen. In ethylene, methane, and coal gas the phenomenon is about the same as in hydrogen. In coal gas, however, the discharge is more brilliant.

Then come carbonic anhydride, chlorine, and ammonia, in which the discharge appears to be of the ordinary nature. In the case of chlorine the discharge is surrounded with a yellow region, filling up nearly the whole tube and exciting strong fluorescence of the glass. With many other gases which were tried no traces of a globular discharge could be observed.

Some interesting characteristics of the phenomena are observed when mixtures of gases or vapours are admitted into the discharge tube. Nothing striking is, however, observed by mixing gases in which the globular spark cannot be formed, nor in mixtures in which these gases preponderate.

The following mixtures gave the most striking results:—

Nitrogen and Carbonic Oxide.—In both these gases the discharge takes place most distinctly. The effect observed in the mixture does not differ materially from that characteristic to each gas, except in the colour of the light. As long as nitrogen does not predominate the mixture behaves almost as though the oxide of carbon were the only gas present. The shape of the luminous mass differs slightly from that which is observed in nitrogen.

A mixture of hydrogen and nitrogen behaves in very much the same manner as the previous mixture.

Nitrogen with a Small Quantity of other Gases or Vapours: Air.—If to nitrogen be added a small quantity of a gas or vapour which alone does not produce the globular discharge, or which only produces luminous masses of great velocity, then the following effects are observed:—The luminous mass diminishes more or less in size, varies in shape, and especially increases in velocity. With successive additions of the foreign gas a small increase in the velocity is noted, until at last the motion can no longer be followed by the eye, without the aid of a rotating mirror. By continuing to slowly increase the foreign gas the discharge takes the form of an ordinary spark, and no luminous mass is observed even in a rotating mirror. It is found under these conditions that the potential necessary for producing the discharge increases, and it becomes necessary to increase the explosive distance of the spark in air, or to diminish the resistance of the discharge circuit.

The mixture of nitrogen and oxygen constituting atmospheric air behaves in the same manner—*i.e.*, the potential necessary for producing the discharge is greater than in nitrogen. The luminous masses are of a less purple red, are longer, and move more rapidly than nitrogen.

Nitrogen and Methane.—In this case the luminous mass is very large at the upper part, and is surrounded with a halo of weaker intensity. Its colour is of a violet red, and not of a purple red, as is characteristic of nitrogen.

Nitrogen, Coal Gas, Acetone, &c.—A small quantity of coal gas—about 1-30th—added to nitrogen, produces a discharge which is shorter and more rounded than in the preceding case. The pale halo which surrounds it takes the form of an ellipsoid, and under certain pressures and with certain proportions of coal gas may become almost perfectly spherical. By producing a prolonged discharge, and if the resistance of the discharge circuit is not too low, the luminous mass will remain stationary in the tube, and remains visible as long as the machine is in action. Sometimes, when the potential is suitably increased, two or more luminous masses are obtained, distributed along the axis of the tube. The last formed mass moves towards the positive electrode, and disappears there; and at the same moment the other mass, which was hitherto stationary, moves towards the positive electrode, oscillates vigorously, and then remains stationary and permanently visible. If the right quantity of coal gas be slightly exceeded, the luminous mass becomes paler and unstable, and oscillates more or less rapidly in the direction of the axis of the tube. By substituting for the coal gas, acetone vapour, ethyl chloride, or ethyl acetate, analogous phenomena to those last described are obtained.

Nitrogen and Sulphuretted Hydrogen.—Nitrogen with traces of sulphuretted hydrogen produces very brilliant phenomena, but unstable, and due, no doubt, to chemical alterations in the mixture. The luminous masses are red at their lower end, and bluish at their upper end. With certain proportions of the two gases the discharge assumes the shape of a comet.

Nitrogen, Bromine, Ethyl Bromide, &c.—Mixtures of nitrogen with small quantities of ethyl bromide, bromine, ethyl iodide, and acetylene, produce under certain pressures very different discharges from those hitherto described, and it is particularly with bromine vapour that characteristic results are obtained. The discharges are very brilliant, much smaller than in pure nitrogen, possessing a great velocity of translation, and in the form of a cone with the lower end diverged. If the explosive distance of the exciter be increased or the resistance decreased, instead of a simple discharge, a compound one is produced, consisting of a large number of luminous cones close together. The shape of these luminous masses depends on the pressure of the gas. If larger tubes be used, the discharges are less brilliant, and have the characteristic, when moving away from the positive electrode, of remaining connected to it by a long and brilliant tail.

Nitrogen and Tetrachloride of Tin.—With mixtures containing a small percentage of the latter gas the discharge consists of a long column of pale green or blue colour, according to the potential, resistance, &c. When the globular discharge is, however, formed, the luminous mass of pink or red colour takes various forms, according to the pressure and proportion of tetrachloride of tin.

Oxide of Carbon and Small Quantities of another Gas or Vapour.—The addition of a small quantity of gas other than nitrogen to oxide of carbon gives rise to effects similar to those obtained by the same additions to nitrogen.

The shape of the luminous mass appears to vary in the same manner as in nitrogen.

If a small quantity of bromine vapour be added to oxide of carbon, luminous masses of a conical form are observed. Their colour is green, instead of red as in oxygen. They are equally brilliant, and present the same characteristics.

Luminous masses of conical shape and white colour have been obtained by adding traces of bromine to a weak mixture of nitrogen and oxide of carbon. The author has obtained similar discharges in a glass tube fitted with the ordinary electrodes, but at a point about one-third of its length; the diameter being reduced to about 2 cm. When the discharge takes place, this portion of the tube becomes luminous, and behaves as an insulated conductor, its ends acting as electrodes, whilst other luminous masses form in the two other portions of the tube.

From these researches the author has been unable to form a complete theory for the phenomenon of the globular spark, but considers that the explanation which he has given with regard to the formation of sparks at the surface of liquids, appears to extend also to sparks in the interior of conducting liquids, or semi-conductors, and consequently to globular discharges.

To offer a complete explanation for the globular discharge, one would have to account not only for the formation and movement of the luminous masses, but also for the fact that they form only in a few gases, and almost exclusively in nitrogen and carbonic oxide. The author considers that the electrolytic theory of discharges would explain the different actions in different gases: these being due to the varying facility with which the atoms forming their molecules can separate or group to form a new molecule, and also to the different rapidity of motion of these free atoms.

MM. BENOIST and D. HURMUZESCU—THE ACTION OF THE "x" RAYS ON ELECTRIFIED BODIES.

(*Comptes Rendus, Vol.* 122, *No.* 17, *April, p.* 926.)

The authors have extended their researches on the specific influence of an electrified body on the rate of dissipation of its charge produced by the x rays, by studying that of the gaseous dielectric in which the body is placed.

In conjunction with the gold-leaf electroscope, was used a metal box capable of being exhausted of its air, and in which was placed an insulated brass plate connected to the gold leaves. The x rays pass through an aluminium window. A first series of experiments has shown that the rate of discharge of the electricity increases with the density, and diminishes with a decrease in the density of the gas. It is greater in compressed air than under ordinary pressure.

It is less in hydrogen than in air, greater in carbonic acid, and still greater in sulphurous acid. A law has been established from a series of experiments, either in air at different pressures or in different gases at the same pressure, with the time taken for the leaves to deflect from the same initial angle to the same final angle in each case.

The law is that the rate of dissipation of electricity by the x rays for the same electrified body, under the same conditions, varies proportionally to the square

root of the density of the gas in which it is placed. The dissipation of electricity by the x rays depends both on the nature of the electrified body, due to a sort of power of absorption depending on its opacity, and also on the nature of the surrounding gas, but happening only by its specific mass; or by its molecular mass when passing from one gas to another.

The authors do not consider that the explanation of the dissipation, is to be found in the hypothesis of an absorption of radiant energy by the molecules of the gaseous dielectric dissociating into free ions, but to that of an absorption of this energy by the electrified body itself, expelling the gaseous molecules condensed on its surface, or even occluded to a certain depth.

The authors have observed in their experiments certain direct indications of the last phenomena.

A. ABRAHAM—ON THE COMPENSATION OF DIRECTIVE FORCES AND THE SENSITIVENESS OF THE MOVABLE-COIL GALVANOMETER.

(*Comptes Rendus*, *Vol.* 122, No. 16, *April*, *p.* 882.)

The effective sensitiveness of a galvanometer with a movable coil, depends on the magnetic field, the movable coil, and the elastic suspension.

This effective sensitiveness can be increased by—

(1) Increasing the intensity of the field.

(2) Diminishing the dimensions of the movable frame.

(3) Diminishing the directive couple of the elastic suspension.

The use of a powerful electro-magnet, and of a coil containing no iron, and whose moment of inertia is equal to that of the mirror, produces in the movable-coil galvanometer a " constant of sensitiveness " which has never been exceeded by movable-magnet galvanometers.

In order to effectively obtain this sensitiveness it is necessary to greatly reduce the directive couple.

The thicknesses of the suspending spring cannot be diminished indefinitely; the alternative is, therefore, to compensate its directive couple. In order to compensate a couple, it is usual to add another one, the directive force of which is to be subtracted. In the particular case of a galvanometer, the torsion of the fibre can be compensated by the use of the weight of the coil. For this purpose the centre of gravity of the coil is placed a little in advance of its axis of rotation, either by so constructing the instrument, or by means of an additional weight. The galvanometer is then tilted backwards, and when compensation takes place the oscillations of the movable arrangement are seen to become slower and slower. After complete compensation the condition of equilibrium becomes unstable. M. Carpentier applied this method to a Deprez-D'Arsonval galvanometer. By adjusting the inclination of the instrument by means of levelling screws, the time of oscillation was increased from one to ten seconds. The effective sensitiveness is then increased one hundred times, and becomes equal to that of a Thomson galvanometer of equal resistance.

A. LAFAY—ON ELECTRIFIED RÖNTGEN RAYS.

(Comptes Rendus, Vol. 122, No. 17, April, p. 929.)

In his previous experiments the author found it possible to collect the electricity carried by electrified Röntgen rays.

The following results were obtained by using a Mascart electrometer in the place of the electroscope. The Röntgen rays, after passing through a conducting membrane, penetrate a Faraday tube of thick lead, by passing through a suitable aperture, and in the interior of which is placed an insulated metallic screen connected to the electrometer.

When the conducting membrane is placed in connection with a positive or negative source of electricity, it is observed that electricity of the same sign is to be found on the conducting screen towards which the rays are directed; the charge of this conductor, which is rapid at first, soon attains a limited value, depending on its shape and nature. If under these conditions the conducting membrane is connected to earth, the screen discharges to zero-potential, as have observed MM. Benoist and Hurmuzescu.

The whole action takes place as though the electrifying membrane and the screen were connected by a badly insulated wire of high resistance; and the author has been able to reprodnce the same experiment without a Crookes tube by placing between the screen and membrane a long cotton thread with its ends connected to earth.

To study the manner in which the rays are electrified, the author has investigated the action of a large number of electrifying membranes, consisting of different metallic sheets superposed in varying numbers, or of sheets of paper and gelatine soaked with a conducting liquid.

The author has found that both for the charge as well as for the discharge of the conducting screen the rate of alteration of the charge is greater, the more transparent the membrane.

Owing to the difficulty of obtaining membranes of exactly the same transparence, it has not yet been possible to ascertain whether there is any specific action due to the nature of the constituent substances.

By dispensing with the electrifying membrane placed in the path of the rays, it was found that the electrometer nevertheless usually indicated a slight positive charge of the conducting screen; the rays ordinarily emitted by the Crookes tube being therefore positive Röntgen rays; but the electrification which they are capable of communicating to the screen which intercepts them is about 20 to 30 times weaker than that produced by the Röntgen rays. These rays have exhibited an appreciable deviation under the influence of a magnet.

The author explains why other workers have failed to deviate the Röntgen rays with much stronger magnetic fields, by the fact that, as shown above, the beam of Röntgen rays is comparable to a badly insulated conductor, and therefore rapidly loses its electrification, and is but weakly electrified at the moment when it passes through the magnetic field, notwithstanding its small distance from the Crookes tube. Researches were made to ascertain the influence of the nature of the metal of the conducting screen on the phenomenon. MM. Benoist and

Hurmuzescu have found that in this case the discharge is greater with denser metals, and the author has found that the bodies which generally produce the most rapid discharge, are those which are most easily charged under the action of the electrified rays. When the screen consists of a thin metallic sheet, it is found that the charge is slower, and discharge more rapid, than with a thicker sheet of the same metal; but under this condition the rays pass through the screen and produce a by-path by acting as conducting wires connected between the posterior portion of the thin sheet and the opposite portion of the Faraday tube. By employing different arrangements for obviating these by-paths, the author observed far less important differences between the charge and discharge of the same metal, under different thicknesses.

In further experiments the author's attention was drawn to another cause producing a loss of charge. By placing a circular screen of equal diameter to the cylindrical beam of rays, at first normal, then inclined to the axis of the beam, it was remarked that in the first position the discharge was slower and the charge more rapid than in the second case. It would appear that the radiations which are not intercepted, owing to the inclination of the screen, act as parasitic conductors, and allow a loss of charge from the back part of the tube. This explanation is, however, insufficient, since, by substituting for the circular disc an elliptical disc, representing the disc inclined at 45°, the discharge was found to be appreciably slower; and consequently the author was led to attribute the loss, at least in part, to the diffused reflection of the rays on the surface of the screen. For the purpose of verifying this, the Crookes tube was placed at the side of the Faraday tube, and in such a position that the rays could not directly pass through its aperture; it was then found, by placing in front of this aperture an inclined metallic screen exposed to the rays, that it was possible to discharge the electrified screen.

From the above experiments it is found that the study of the phenomenon of the charge and discharge of conduct rs by the Rontgen rays is subject to causes of error which are difficult to avoid in an absolute manner; the results also show that the charge cannot exceed a limited value, depending on the shape of the conductor, on its nature, and on its position within the protecting tube.

C. JACQUIN—THE ELECTRIC TRAMWAY FROM "LA PLACE DE "LA RÉPUBLIQUE" TO ROMAINVILLE.

(L'Éclairage Électrique, Vol. 7, No. 18, May, p. 222.)

The Romainville line constitutes the first permanent installation of the Claret-Vuilleumier tramway system, which had worked for six months under an experimental form at the Lyons Exhibition. The construction of the line was commenced in September, 1895. At the beginning of March the generating station was supplying current for arc lamps along the track.

In this tramway system, the conducting rail, from which current is collected by means of shoes fixed under the cars, is placed on a level with the track, and is divided into sections, spaced about the length of a car, and a little shorter in *length*. These sections are connected, in groups of 18, to automatic devices named

"distributors;" the latter being connected in a permanent manner to a feeder or main insulated cable laid in the earth, and connected to the positive pole of the generating dynamos. The return circuit is through rails and earth.

The distributing apparatus, which constitutes the essential part of the system, presents some analogy with the distributor of the Baudot telegraph. The distributor sends the current successively and automatically to the sections at the time when the car is passing over them. The sections are therefore only electrified at the time when cars are passing over them; at other times they are completely insulated.

At Lyons, the conducting rail consisted of a series of strips of iron 4 metres long encased in bitumen, and spaced at about 4 metres. At Paris this method of construction was not authorised, on account of the danger to horse traction; the only arrangement tolerated being metallic slabs having the same surface as ordinary pavement.

To conform with this regulation, metallic slabs were laid at a distance of 2·5 metres apart, insulated in bitumen, and connected in pairs to an insulated conductor of 8 sq. mm. section, placed a few centimetres below the surface of the ground. Two consecutive slabs therefore only constitute a single section of rail, and this arrangement necessitates using contact shoes 3·3 metres in length, consisting of a strip of iron fixed under the truck by means of springs; the above length being sufficient to bridge over the space between two sections.

The 19 sections controlled by a single distributor are connected to this apparatus by cables of 8 sq. mm. section insulated with rubber, carried in transverse cast-iron pipes 60 mm. diameter, and then laid longitudinally in the same trench as the main distributing cable. The latter is insulated with jute, and covered with a protecting envelope of lead and iron. The feeder from the generating station to the Place de la Republique is about 5,100 metres long, and has a section of 297 sq. mm.; and that from the station to Romainville is 2,400 metres long, with a section of 325 sq. mm.

The distributors, which are 40 cm. diameter and 20 cm. deep, are contained in circular cast-iron boxes, placed every 95 metres, in a line with the cable trench, along one of the pavements. Special precautions are taken to prevent water from injuring the distributors, and also that, if needed, any distributor may be readily replaced by a spare one carried on each car.

The length of track in Paris is 3,300 metres, and out of Paris 3,300 metres. The track in Paris is nearly all inclined, and in the Avenue de la République the slope reaches 46 mm. per metre. The line has some sharp curves, some having a radius of 30 metres.

The depôt adjoining the generating station is capable of holding 50 cars.

The generating station contains 3 semi-tubular boilers and three steam engines of 200 H.P. The shaft is 38 metres high. Each engine drives by belt a dynamo of 140 kilowatts output.

The engines, of the Garnier type, are single-cylinder condensing. The dynamos, constructed by the firm of Hillariet, are 4-pole, and over-compounded for a potential of 500 volts.

The arc lighting is carried out by 14 circuits, each containing nine lamps in series, and each branched from the two main cables.

The cars are 8·6 metres long, carry 56 passengers, and are provided with a luggage store. The cars are lighted by two circuits of five 16-C.P. lamps in series, one being a spare circuit, which can be switched on in the event of one of the lamps breaking.

The car is driven by two motors, fixed under the frame by means of springs, and which drive the two axles by spur gearing, reducing the speed to one-fifth.

These two motors are arranged to work either in series or in parallel, and a further alteration in speed can be obtained by a rheostat. Both the conductor and driver can control the car by means of a screw brake.

There will be about a five-minute service.

ERIC GERARD and G. HENRARD—NOTES ON POLYPHASE CURRENTS.

(*L'Éclairage Électrique, Vol.* 7, *No.* 18, *May, p.* 200.)

The following notes were compiled by the authors from modern Swiss and German practice.

The points most discussed in connection with polyphase currents are the frequency, the number of phases, and the type of alternators.

The lower the frequency, the better for the motors; but where lamps are employed a frequency of 50 appears to be generally adopted.

Arc lamps fluctuate slightly at this frequency, but the fluctuations are inappreciable at a distance of a few metres when the arc is enclosed in an opal globe and the upper carbon fitted with an enamelled iron reflector.

Besides the well-known advantages of polyphase motors, another point in favour of the polyphase system is that the generators are more economical than monophase generators.

It has been argued that two phases are preferable to three phases, owing to the greater facility in making lamp connections and better regulation. The three-phase has, however, the advantage of a 25 per cent. saving of copper over the monophase and biphase systems for the same limited tension between the conductors; and, for this reason, the triphase system is advocated by many of the important Continental firms.

The generators may be divided into three classes. To the first type belong the machines with rotating armature and fixed field, but these are not used for large powers.

To the second type belong the machines with a stationary armature and rotating field magnet. The latter more often consists of radial poles, each fitted with an exciting coil and suitable pole-pieces.

In some of Messrs. Brown Boveri's machines there is a coil to every other pole, these being alternately of cast iron and wrought iron.

Notwithstanding the economy of a single magnetising coil, an objection against their use arises from expansion and motion of the windings, and

consequent wear of insulation, with the risks of short-circuiting. Another objection against single-coil field magnets is the large armature reaction, producing a drop amounting sometimes to 30 per cent., owing to the large dimensions of the pole-pieces.

The effect of too great an armature reaction in the generator can, however, be corrected by connecting, near the motors, a synchronous motor having a large moment of inertia, running light and acting as a fly-wheel. If there be a drop in pressure on starting the motors, the synchronous motor will act as a generator by virtue of its inertia and momentarily supply energy, thus minimising the drop in pressure.

To the third type of generators belong the machines with stationary field and armature coils and revolving iron inductor. This type of machine was at first employed by Messrs. Stanley and E. Thompson, and developed by several Continental firms. The advantage of this design is that all moving contacts are avoided, and the design is very strong.

The "drop" of a generator should not exceed 15 per cent. on motor circuits, and 5 per cent. on lamp circuits.

The power-factor of modern motors is between 0·65 and 0·85 per cent., according to their output.

In the case where both motors and lamps are used it is advisable to assume a maximum power-factor of 0·70 to 0·75 per cent. Polyphase motors recommend themselves by their simplicity of construction. Motors of 1-10th to 10 H.P. can be wound for pressures of 100 to 500 volts, those of 10 to 30 H.P. for pressures of 500 to 2,000 volts. Motors of 50 H.P. can be wound for 3,000 volts, and those of 75 H.P. for 5,000 volts.

Certain points of primary importance in the design of polyphase motors have rendered the different makes very similar to one another. The necessity of reducing the air gap has led to the use of channel windings. All iron parts must be laminated. The armatures are all drum-wound, as this produces the least magnetic leakage. The armatures of small motors have usually squirrel-cage windings. The point on which makers differ most is in the method of starting. This is usually done by introducing resistances in the armature circuit, but in the case of large motors there is a tendency to use loose pulleys or friction clutches. Experiments made by the authors at Messrs. Siemens & Halske and Messrs. Brown Boveri's works show that the motors start with normal torque with the normal current, twice the torque with twice the current, and three times the torque with three times the current.

An automatic method for starting motors, employed by the firm of Siemens & Halske, consists in using two circuits for each of the phases on the armature. These circuits, having different numbers of turns, are connected to oppose one another at starting, so that their opposing electro-motive forces only produce the normal current. When the normal speed is attained, a sliding ring on the spindle connects the coils in parallel, as in a squirrel-cage winding.

Under special conditions, such as in coal mines, an auto-transformer is used for starting the motor.

The regulation of speed is a difficulty with polyphase motors. The speeds can

be varied in the ratios of 1 : 2 : 3 by altering the connections of the field-magnet poles; but in order to obtain gradual variations it is necessary to introduce resistances in the armature circuit, which lead to a serious loss of energy; in many cases it is advisable to have recourse to mechanical means.

Polyphase transformers may either consist of a set of single transformers, or they may be combined to suit the number of phases. The latter system is the more often employed. The drop should not exceed 2 per cent. with a lamp load, and 6 per cent. for a motor load. In the case of large motors it is advisable to provide a transformer of 50 per cent. above the normal output, and it is well to run several motors from the same transformer, and to provide separate transformers for the lamps.

If in a three-phase distribution the different branches be unequally loaded, there will be variations of pressure, which are difficult to regulate at the station. The motors connected on the three circuits have a tendency to equalise the pressure.

With this object, instruments called "balancers" are connected to the secondary circuit, consisting of three iron cores, similar to those used for transformers, and wound with three coils connected in triangle on the three circuits. If there be a fall in pressure on one of the coils, the two others will receive stronger currents, and raise the pressure of the defective branch. The sections of conductors for alternating-current distribution are limited by the Thomson effect. The sections rarely exceed 300 to 350 mm. In the case of overhead conductors it is advisable, in order to minimise impedance, to subdivide the conductors and place them alternately.

Oil insulators are no longer employed, on account of the trouble of maintenance; large insulators with double or treble mantles being preferred. In underground work either twisted or concentric conductors are employed, in order to diminish impedance. The phenomenon of resonance, due to the combined effect of self-induction and capacity, may on open circuit allow large currents to pass into the cables. As this effect increases largely with the potential, it is one of the conditions which limits the potential for underground mains. The kind of insulation employed also limits the potential in underground mains.

Few firms advocate more than 4,000 volts for paper insulated cables. For higher voltages than this rubber is employed, but this does not last as long as cellulose. The voltage is also limited by the length of the cable, on account of its capacity.

The Dresden and Chemnitz stations are described as being typical of Continental practice.

The Dresden station supplies current on the three-phase system to lamps and motors; the latter are all connected to a single branch, in order to secure steady running for the lamps.

The generating station contains four fly-wheel alternators of 300 H.P. each, coupled direct to Hofner tandem engines, running at 100 revolutions per minute. The speed of the engines can be varied from the switch-board, to facilitate running the machines in parallel; this being done by means of a motor which alters the counterweight of the governor.

The generators work at a low tension, and step up from 100 to 3,000 volts.

Most of the transformers have an output of 100 kilowatts. The sub-station transformers are of 50 kilowatts output. All the high-tension circuits are placed overhead, with a guard wire placed under the conductors.

With regard to the Chemnitz station, this at present only contains 450 H.P., but is being extended to 1,000 H.P. As in all Siemens & Halske installations, the current is distributed on the three-phase system, and supplied by generators working at 2,000 volts for each branch. The lamps and motors are distributed over the three phases. The boilers are of the Steinmuller type, with automatic stokers. The engines are of the triple-expansion vertical type, fitted with a special speed indicator similar to that used at Dresden. Each alternator is of 150 kilowatts output, and is direct-coupled to the engine.

The concentric paper insulated cables are placed underground.

The transformers are of 50 kilowatts output, placed in small houses above ground.

All the primary circuits are connected together, as is also the case with the secondary. The radius over which a transformer works is 500 metres, and the loss allowed on each branch connection 1½ per cent. The drop in pressure at the secondary terminals of the transformer amounts to 4 per cent. between no load and full load. The station voltage is regulated to keep this constant by the aid of an auxiliary winding on the alternator. This winding is also used for synchronising the alternators.

Power and light are charged for at different rates; the former at 18 pfennigs per kilowatt-hour, and the latter at 70 pfennigs per kilowatt-hour.

The company will only employ motors which on starting do not produce a variation of more than 2 per cent. in the voltage.

D. A. GOLDHAMMER—NOTES ON THE NATURE OF THE "x" RAYS.

(*Wiedemann's Annalen, Vol.* 57, *No.* 4, *p.* 635.)

The author traverses the hypothesis of Professor Röntgen that these rays consist of longitudinal vibrations of the ether, and proceeds to compare their properties with those of ultra-violet light.

It appears to be incontestable that the x rays are not cathode rays. The new rays are propagated rectilinearly, and produce fluorescence and chemical action, which are the properties of ordinary ultra-violet rays. Moreover, many substances are permeable to the x rays which are partly permeable and partly impermeable to the known rays.

According to present views on the dispersion and absorption of rays, this property of the new rays is also not peculiar thereto; it is only necessary to call to mind the properties of rock salt, iodine solution, and dark cobalt glass. For ordinary ultra-violet light, quartz is very permeable, glass and calc-spar are less permeable, and air, ammonia, and bisulphide of carbon vapour quite impermeable. A thin film of silver ($1{\cdot}5 \times 10^{-6}$ cm. thick), as is known, only allows the invisible rays of about $3{\cdot}4 \times 10^{-5}$ cm. wave-length to pass through.

That property of the x rays which appears so astonishing to the general

public, and which will undoubtedly find many practical applications, does not, therefore, distinguish it from other known rays. Moreover, even to Herr Röntgen, only the following properties of the new rays appear unexplainable:—

(*a*) That in passing from air into water, bisulphide of carbon, aluminium, rock salt, glass, zinc, &c., they experience no observable refraction;

(*b*) That, apparently, they cannot be regularly reflected from the said substances;

(*c*) That they cannot be polarised by the usual means;

(*d*) That the absorption thereof is not influenced so much by any property of substances as by their density.

The author entirely agrees with Professor Röntgen in so far as that none of the rays heretofore known to us possess *exactly similar* properties. But this does not exclude the hypothesis that the x rays may be ultra-violet light of extremely short wave-length which was previously inaccessible to us.

In the first place, these premises directly explain the apparently irregular reflection of the x rays. Their wave-lengths are too small in comparison with the irregularities of surfaces polished in the usual manner; naturally, such surfaces cannot serve as polarisers for the new rays. In this way, properties (*b*) and (*c*) appear to be explained.

If we compare the behaviour, for example, of flint glass with regard to visible light and the x rays, it results that this substance is relatively impermeable for the latter; with the exception of air, amongst the substances experimented upon by Herr Röntgen, none were so permeable to the new rays, when in layers several centimetres thick, as water and glass are for the visible rays.

The author compares the behaviour of the new rays towards metals and other materials, with the behaviour of fuschine, aniline, and similar solutions towards visible light. With fuchsine solutions, the absorption, for example, is, *ceteris paribus*, proportional to the concentration. Putting this result against Table V. of Herr Röntgen, we immediately see that the density of substances plays somewhat the same *rôle* as the concentration of the fuchsine solution for visible light. In other words, the molecules of the substance (and different substances) embedded in the ether act towards the x rays in somewhat the same way, as the particles of fuchsine in water and the like act with regard to the ordinary light rays. This analogy can be carried still further. Prisms of fuchsine solution give the so-called anomalous spectrum: is it not possible that the substances investigated by Herr Röntgen show an anomalous dispersion of the x rays?

In the case of an anomalous dispersion it is known that the index of refraction, n, decreases with the wave-length, λ; so that, according to Wernicke, for solid fuchsine, $n = 2{\cdot}293$ when $\lambda = 598 \times 10^{-7}$, and decreases to $1{\cdot}224$ when $\lambda = 448 \times 10^{-7}$ mm. The observations of Du Bois and Rubens on prisms of Fe, Co, Ni, leave no doubt as to the existence of a very marked anomalous dispersion of light in these media: with a variation of wave-length from 671×10^{-7} mm. to 431×10^{-7} mm., n fell from 3·12 to 2·05, from 3·22 to 2·10, and from 2·04 to 1·54. Would it not be possible that n for aluminium and the like would be still smaller for extremely short wave-lengths? We have, moreover, in absorbing media (such as metals), the index of refraction lying very near to 1, and

also smaller than 1; as is known, Kundt found for Ag, $n = 0{\cdot}27$; Au (white, an alloy of Au and Ag), $n = 0{\cdot}58$; and Au (blue), $n = 1$.

It will be readily understood, without further discussion, that the fact of n being $\leqq 1$ only points to a special kind of wave-propagation in absorbing media, and does not actually give a smaller or equal value for the velocity of light in ether.

Consequently, the properties (a) and (b) appear to us to be explained. For rays of extremely short wave-length, the absorbing power of materials may well be only influenced for the most part by their density; as regards refraction, however for red or yellow rays, for example, several substances are found the indices of refraction of which are about the same. If n is very near to 1 for the materials investigated by Herr Röntgen, then quite similar properties of these substances can be understood.

It may be noticed that several theories of dispersion, for all substances, give $n = 1$ when $\lambda = 0$.

Collecting the above results, we come to the following conclusion:—The beautiful and highly interesting phenomena which Herr Röntgen has discovered are in agreement with the assumption that the x rays are ordinary transverse ether vibrations, the wave-length of which is much smaller than that of the ultra-violet rays known heretofore.

Should this actually be the case, the x rays may possibly (if not necessarily) be present in the spectrum of the arc light, and of platinum and lead vapour. It is very difficult to believe that the cathode rays and the fluorescence produced thereby should be the only method available to us for the production of the new rays.

ANTON KRUMMENACKER—ABSOLUTE MEASUREMENTS OF THE ELECTRIC SURFACE CONDUCTIVITY OF GLASS WITH DIFFERENT DEGREES OF MOISTNESS OF THE SURROUNDING AIR.

(*Beiblätter, Vol.* 20, *No.* 4, *p.* 283.)

Over a sulphuric acid of definite concentration there is a definite pressure of the water vapour still present. In this manner the author obtained different states of moisture by making different concentrations of sulphuric acid, the relative moisture corresponding to any given concentration being taken from Regnault's tables. All measurements of the conductivity of glass—to the determination of which only the Siemens, or condenser, method proved workable—were carried out by observing the time of charging the condenser. The battery consisted of 12 small Daniell's cells. The conductivity measurements of one and the same glass showed great variations, due to foreign influences, and thus the conductivities of glass from different sources naturally differed very much from one another. In this way the author found, for example, the resistance of the surface of a strip of a lead glass (1 sq. cm. large) to be, in round numbers, 6,000, for a soda glass 700, megohms. A glass surface formed by solidifying the fluid material conducted

electricity in moist air less readily than a polished surface, and this, again, much less easily than surfaces produced by simply dull grinding or by fracture.

EDM. VAN AUBEL and R. PAILLOT—A COMPARISON OF THE ELECTRICAL CONDUCTIVITY AND THERMAL CONDUCTIVITY OF ALLOYS.

(*Beiblätter, Vol.* 20, *No.* 4, *p.* 284.)

The authors have investigated the conductivity of such alloys the electrical resistance of which is very great. The experiments extended to aluminium, bronze, konstantan, and iron-nickel. The thermal conductivity was determined by Despretz's method, which has also been used by G. Wiedemann and Franz. The rods were 0·4 metre long and 0·009 metre diameter; they were nickelled and carefully polished. Since very different values were obtained for the thermal conductivity of electrolytic copper in the researches of Berget, L. Lorenz, &c., the authors compared the thermal conductivity of the alloys with that of cadmium, the thermal conductivity of which has been very accurately determined by L. Lorenz. One end of the rod to be tested was fastened in the cover of a cylindrical box of brass through which steam was circulated. The temperature at various points of the rod was measured by means of a thermo electric couple, which consisted of iron and konstantan wire of 0·3 mm. diameter. Small holes of 0·4 mm. diameter and 1·5 mm. deep were drilled in the rods at distances of 4 cm. apart. In each hole was placed a drop of oil in which dipped one of the soldered junctions of the thermo-electric couple, whilst the other dipped into a test tube filled with oil kept at the temperature of the surroundings. A Wiedemann's mirror galvanometer was used for these measurements. The electric conductivity was measured by means of a Thomson's double bridge. The law of Wiedemann and Franz does not hold for alloys of high specific resistance; it probably only holds exactly for pure metals of good conductivity.

———	Electric Conductivity compared with Cadmium.		Thermal Conductivity compared with Cadmium.
	At 0°.	At 15°.	
Cadmium	1	1	1
Tin	0·650	0·644	0·711
Aluminium-bronze... ...	0·603	0·630	0·807
Konstantan	0·139	0·148	0·300
Iron-nickel	0·082	0·086	0·193

K. E. GUTHE and L. J. BANGS—THE ELECTRICAL CONDUCTIVITY OF CONCENTRATED SULPHURIC ACID.

(*Beiblätter, Vol.* 20, *No.* 4, *p.* 285.)

According to Kohlrausch, Bouty, and Ostward, the conductivity curve of aqueous solutions of sulphuric acid reaches a minimum at a concentration which corresponds approximately to the hydrate $H_2 SO_4 + H_2 O$. This minimum is less definite at higher temperatures. From a large number of determinations, the authors have come to the conclusion that all curves have a minimum at the same molecular volume of 32·1. The molecular volume, and not the concentration, determines also the conductivity. The temperature coefficient increases as the conductivity decreases. The conductivity of solid $H_2 SO_4 + H_2 O$ increases at first slowly with the temperature; between 0° and 7·5° the increase is very great. The conductivity curve of fluid $H_2 SO_4 + H_2 O$ cuts that of the solid substance at an angle of about 45°. During melting there is also a sudden increase in the variation of the conductivity.

CH. MARGOT—THE ELECTRO-PLATING OF ALUMINIUM WITH COPPER.

(*Beiblätter, Vol.* 20, *No.* 4, *p.* 287.)

Adhesive coats of copper can be obtained on aluminium by the following process:—The aluminium is cleaned in a warm solution of an alkaline carbonate, and its surface thus made rough and porous; it is then thoroughly washed in running water and dipped into a hot solution of hydrochloric acid of about 5 per cent. strength, and again washed in clean water; it is then placed in a somewhat concentrated acid solution of copper sulphate, until an uniform metallic deposit has formed; it is then washed again in plenty of water, and brought back into the copper sulphate bath, when an electric current is passed until the coating is of the desired thickness.

— CLASSEN—TO INCREASE THE SENSIBILITY OF THE DEPREZ GALVANOMETER.

(*Beiblätter, Vol.* 20, *No.* 4, *p.* 291; *Elektrotechnische Zeitschrift, Vol.* 16, *pp.* 676–677, 1895.)

The observations were made on a Deprez galvanometer constructed by Edelmann, of Munich. The most important results of the calculation are the following:—1. In order to increase the sensibility of the Deprez galvanometer, the horizontal diameter of the coil should be made as small as possible. 2. The magnetic field should not be very strong, the use of electro-magnets being excluded. The suspension fibre must be as thin as possible. In order not to load the suspension too heavily, fine aluminium wire should be used for winding the coil, since the greater resistance thereof can be compensated for by employing a stronger magnetic field. With a higher resistance the damping will be less, and a stronger field can be used. On the other hand, the torsional force of the suspension will be

limited by the fact that a certain point will be reached at which it will no longer be possible to conduct the current without injuriously affecting the torsional rigidity of the material. The author is of the opinion that the construction of the Deprez galvanometer will be so far developed that it will not be behind the best astatic mirror galvanometers as regards sensibility and convenience. This point has not yet been reached because the magnetic fields were too strong, and consequently, in order not to have too powerful damping, powerful torsional forces or directive couples were employed; the maximum sensibility, therefore, could never be reached.

C. P. STEINMETZ—THE LAW OF HYSTERESIS AND THE THEORY OF INDUCTIVE RESISTANCE IN CLOSED IRON CIRCUITS.

(*Beiblätter, Vol.* 20, *No.* 4, *p.* 292; *Elektrotechnishe Zeitschrift, Vol.* 16, *pp.* 623–625, 652–655, *and* 666–669, 1895.)

In the first place the author discusses the values which the coefficients η and x assume in the formula, $H = \eta \,.\, B^x$, giving loss of energy by hysteresis through magnetic friction. For the loss of energy due to static dielectric hysteresis in a dielectric, according to R. Arno, a similar relation holds—$H = \delta \,.\, F^x$, where F is the intensity of the induction in the dielectric. The coefficient in this case also is very near 1·6. With the frequencies and field strengths of the values occurring in alternate-current condensers, the author found the loss of energy due to dielectric hysteresis proportional to the square of the field strength. The author shows that the formula $H = \eta \,.\, B^x$ in a high-voltage 500-kilowatt alternate-current generator gives, taking $x = 1{\cdot}6$, a very close agreement with the observed losses from hysteresis. The lowest values observed for $\eta \,.\, 10^3$ for steel and iron plate for use in electrical machinery, lie between 1·24 and 1·94; the highest observed values, between 4·27 and 5·3. The process of manufacture, whether for steel or iron plate, makes no difference, and the chemical composition also appears to have no influence on the value of η. On the contrary, specimens of almost identical composition gave quite different values of η.

———	Iron.	Steel.	Iron.
$\eta \,.\, 10^3$	1·35	3·22	4·77
Total foreign constituents in percentage	0·459	0·462	0·509
C	0·086	0·090	0·081
P	0·069	0·063	0·077
Si	0·032	0·049	0·028
Mn...	0·242	0·230	0·293
S	0·030	0·030	0·030

The chemical composition is almost the same in the three kinds of iron. Accordingly, the molecular magnetic friction is essentially a physical property.

In the experiments of Ewing, the exponent x in the formula $H = \eta . B^x$ varies somewhat with different magnetic inductions, and gives, in its variation, the three characteristic features of the curve of magnetisation.

Hysteresis and molecular magnetic friction are not identical, but hysteresis is one of the phenomena of molecular friction. In stationary alternate-current apparatus, such as transformers, hysteresis and molecular friction are almost identical. In rotating apparatus, on the contrary, the difference between molecular friction and magnetic hysteresis can be very considerable. In order to distinguish clearly between the phenomenon of magnetic hysteresis and the molecular magnetic friction, the author brings forward the only relation which exists between the two. If an alternating magnetic flux circuit neither receive energy from the exterior, nor work be done externally by the magnetic flux circuit, the energy converted into molecular magnetic friction from the magneto-motive force is yielded in the form of magnetic hysteresis.

In the third part of the paper the author gives the theory and calculations relating to inductive resistances containing iron. Together with the known formulæ for the calculation of the combined resistance of a number of separate resistances in series with one another, and a number of resistances in parallel with one another, in a continuous-current circuit, the author shows that the combined impedance of a number of impedances in series with one another is equal to the sum of the separate impedances, and that the combined "admittance" of a number of conductors in parallel with one another is equal to the sum of the separate admittances expressed as complex magnitudes. By "admittance" is to be understood the reciprocal of the impedance. As the principal causes of loss of energy in alternate-current circuits the author cites the following:—1. Molecular friction: (*a*) Magnetic hysteresis; (*b*) dielectric hysteresis. 2. Primary circuit: (*a*) Loss of current through the insulation—silent discharge; (*b*) eddy-currents in the conductors, or irregular distribution of the current therein. 3. Secondary circuit: (*a*) Eddy- or Foucault-currents in surrounding magnetic material; (*b*) eddy-currents in adjacent conducting bodies; (*c*) induced currents in adjacent conductors, or mutual induction. 4. Induced electric discharges—electrostatic induction. Of these losses, the author considers the following to be the most important:—Magnetic hysteresis and eddy-currents in their influence on the equivalent resistance.

In order to exactly define the nature of the distortion of the current-wave produced by the hysteresis, the E.M.F. is taken as a sine wave. The author takes four hysteresis loops with the maximum values of $B = 2{,}000$, $6{,}000$, $10{,}000$, $16{,}000$, and the corresponding maximum values of the E.M.F.: $F = 1{\cdot}8$, $2{\cdot}8$, $4{\cdot}3$, and 20 ampere-turns per cm. The loops correspond to medium value iron or steel plate, which have the coefficient of hysteresis $\eta = 0{\cdot}0033$. In four figures the magnetising current-waves of an iron magnetic circuit are shown corresponding to the four hysteresis curves, while the E.M.F. and the magnetic induction are taken as sine waves. The current-curves, F, are not sine curves, but are of a complex nature; they appear inflated on the ascending side, and hollow on the descending side. Each of such distorted current-curves can be resolved into two components—a sine curve, called the "equivalent sine curve," of similar intensity and similar energy value to the distorted curve, and a wattless residual term of higher

frequency, which consists essentially of a wave of three times the periodicity. Thus it follows that in any alternate-current circuit the E.M.F. and current-curves of any form can be replaced by the equivalent sine curves of E.M.F. and current-strength—that is to say, by sine curves which have the same effective value and the same energy value. The phase difference of the equivalent sine curves will be taken as the equivalent difference of phase. The equivalent sine curve of the magnetising current precedes the magnetisation; this angle of advance can be expressed as the angle of hysteresial phase difference, or lead.

The results of the investigation are the following:—The hysteresial conductance of a complete iron magnetic circuit is proportional to the coefficient of hysteresis, η, the length of the magnetic circuit, L; inversely proportional to the 0·4th power of the E.M.F., E, and to the 0·6th power of the frequency, N, and of the cross section, S, of the magnetic circuit, and to the 1·6th power of the number of turns, n, of the electric current. The absolute admittance v, of an electric circuit of zero ohmic resistance is proportional to the magnetic reluctance (= magnetic resistance), and inversely proportional to the frequency N, and to the square of the number of turns n. Moreover, in an electric circuit completely enclosed by iron, such as in alternate-current transformers, the absolute admittance v, is inversely proportional to the frequency N, the permeability μ, to the cross section S, and to the square of the number of turns n; and directly proportional to the length L, of the magnetic circuit. Moreover, in an inductive electric circuit entirely enclosed in iron, the angle of hysteresial phase advance α, depends exclusively on the magnetic constants, the permeability μ, and the coefficient of hysteresis η, as well as on the maximum magnetic induction B, since $\sin\alpha = 4\,\mu\,\eta/B^{0\cdot4}$. Since α is independent of the frequency, form, and length of the magnetic and electric circuits enclosed by iron, the hysteresial angle of advance is the same when the magnetic induction is the same, if the quality of iron is the same. Amongst the final deductions we note that in open magnetic circuits the conductance is the same as in closed magnetic circuits of similar volume of iron and induction. In closed magnetic circuits admittance $\left(=\dfrac{\text{total current}}{\text{total E.M.F.}}\right)$, conductance $\left(=\dfrac{\text{energy current}}{\text{total E.M.F.}}\right)$ and susceptance $\left(=\dfrac{\text{wattless current}}{\text{total E.M.F.}}\right)$ can only be taken as approximately constant within very narrow limits.

As regards the influence of Foucault currents, the author comes to the following conclusions:—The loss by eddy-currents is proportional to the square of the E.M.F., and proportional to the electric conductivity of the iron. Moreover, the component of the conductance of the inductive electric circuit due to eddy-currents is a constant of the electric circuit, independent of the E.M.F., frequency, &c., and proportional to the electric conductivity of the iron. The eddy-currents also cause an advance in the phase of the exciting current relatively to the magnetisation; it, however, causes no distortion of the wave-form, as does the hysteresis. The angle β, of the eddy-current advance is given from $\sin\beta = \rho/v$, where ρ is the eddy-current conductance of the electric circuit, and v the absolute admittance. Further, the author estimates the eddy-current coefficient ϵ, for laminated iron and for iron wire: ϵ depends only upon the thickness of the

iron plate or on the diameter of the iron wire. Finally, the author gives, as an example of the calculation of alternate-current circuits containing iron, the derivation of the general equations of alternate-current transformers.

J. TUMA—MEASUREMENTS WITH ALTERNATE CURRENTS OF HIGH FREQUENCY.

(*Beiblätter, Vol.* 20, *No.* 4, *p.* 300.)

The author gives a method whereby measurements of resistance can be made with oscillating currents. When a rapidly alternating current flows through a conductor of very small cross section, it may be assumed that the current-density is uniform over the whole cross section. If the heat generated—which in this case is due to the oscillating current—be measured, and also that generated by the passage of a continuous current through the same conductor, the amount of heat generated in each case, in equal times, will be in the proportion of the mean squares of the current-strengths. A conductor of very small cross section can also be used for the measurement of the intensity of oscillatory discharges.

If a thick wire, B, be put in series with the wire, A, of small cross section, the relation between the amounts of heat generated in the two wires when continuous currents of different strengths are passed through them, remains constant; this, however, will, generally speaking, not be the case when oscillating currents are passed through the wires. If W be the heat generated in the wire B, and W_1 that generated in the wire A when the wires are in series with one another and a continuous current of intensity J is flowing through them for a time t, and W' and W_1' the corresponding quantities of heat generated by the application of an alternating current of intensity J' during a time t'; moreover, let w_1 be the resistance of the wire A_1, w the resistance of the wire B for the continuous current, and w' that for alternate currents: then we have,

$$\frac{w'}{w} = \frac{W'}{W_1'} \cdot \frac{W_1}{W}, \text{ and } J' = J\sqrt{\frac{W_1' t}{W_1 t'}}.$$

If a Bunsen ice-calorimeter be used, and l, l_1, l', and l_1' be the corresponding distances through which the meniscus in the capillary tube of the calorimeter is moved, then

$$\frac{w'}{w} = \frac{l'}{l_1'} \cdot \frac{l_1}{l}, \text{ and } J' = J\sqrt{\frac{l_1' t}{l_1 t'}}.$$

From the combined results it is deduced that the ratio $\frac{w'}{w}$ increases with increased thickness of the conductor and with the frequency of the current. From measurements on German silver wires it was found that the ratio $\frac{w'}{w}$ approached nearer to unity as the specific resistance increased. That the resistance was dependent on the current-strength was very noticeable, especially in a 2 mm. and a 3·1 mm. thick iron wire.

K. ZICKLER—ON THE CHEMICAL ACTION OF THE RÖNTGEN "x" RAYS.

(*Elektrotechnische Zeitschrift, Vol.* 17, *No.* 15, *p.* 232.)

The chemical action of the Röntgen x rays was pointed out by Röntgen, and after him by many others, by the decomposition of silver salts on photographic plates. These investigations, however, have not yet enabled it to be determined to what this action is to be attributed—whether, as was stated by Professor Röntgen in his original paper, the chemical action is exercised directly on the silver salts of the plate by the Röntgen rays, or whether this action is caused by the light of the fluorescence which the x rays produce in the glass plate, or possibly in the layer of gelatine.

The author has recently made experiments with a view to answering this question.

The vacuum tube was enclosed in a light-tight cardboard box, the space in which the experiments were made being completely darkened, so that bare photographic plates could be employed.

In the first experiment the object (a purse with a double bow, in the innermost compartment of which was a coin and a small key) was applied to the rear side of a screen of platino-cyanide of barium opposite to the cathode tube; and on the turned-away side of this screen, bearing the fluorescent coating, was laid the sensitive side of the photographic plate. During the action of the x rays, which lasted five minutes, the fluorescence of the screen was seen very clearly through the photographic plate, and also the shadows of the metal parts—the bows, the coins, and the key—of the object exposed by the x rays.

In the second experiment, directly following the other, the platino-cyanide of barium screen was replaced by an ordinary paper screen. Otherwise, the arrangements were exactly the same as in the first experiment. The photographic plate was of the same composition. The time of exposure was again exactly five minutes During the exposure not the least trace of fluorescence was to be noticed on the plate.

On developing, it was found that the plate in the second experiment showed perfectly sharp picture of the metal parts of the object; whilst the picture obtained in the first experiment had suffered a small loss in sharpness, in so far as the platino-cyanide of barium screen was simultaneously shown upon it. As regards the latter, it may be mentioned that, most probably to obtain a better hold for the crystals, the platino-cyanide of barium was spread on a wide-meshed fabric, and the positive showed the image of this fabric in white lines.

The result of the two experiments, especially the second, points to a direct action of the x rays on the silver salts of the plate; or, at least, that, in the above experiments, this action was clearly the more prominent one.

The author does not claim to have settled the question by these experiments, and has in view some further researches in which he proposes to use sensitive films of similar composition spread on plates of ordinary and uranium glass.

CLASSIFIED LIST OF ARTICLES

RELATING TO

ELECTRICITY AND MAGNETISM

Appearing in some of the principal Technical Journals during the Month of MAY, 1896.

S. denotes a series of articles. I. denotes fully illustrated.

ELECTRIC LIGHTING AND TRANSMISSION OF POWER.

Dr. O. Feuerlein—The Electric Lighting of Theatres, with special regard to the Siemens & Halske System.—*E. T. Z.*, vol. 17, No. 19, p. 278 (I.).

Anon.—The Raworth High-Speed Steam Engine for Electric Lighting.—*E. T. Z.*, *ibid.*, p. 288 (I.).

Anon.—The Probst System of Junction Boxes for High-Tension Alternating Currents.—*Ibid.*, No. 21, p. 314 (I.).

Dr. G. Pasch—On the Influence on the General Pressure of a Multiphase System due to the Uneven Loading of One of the Phases.—*Ibid.*, No. 22, p. 326 (I.).

J. Pojatzi—On the Question of the Best Distance between Transformers.—*Ibid.*, p. 329.

Anon.—The Electric Lighting and Transmission of Power in the Works of R. Oldenbourg, Munich.—*Ibid.*, p. 331 (I.).

Anon.—Transmission of Power at Romagnano-Sesia (Italy).—*Ecl. El.*, vol. 7, No. 19, p. 266.

A. Monmerque—The Control of Electric Installations.—*Ecl. El.*, vol. 7, No. 19, p. 267.

C. E. Guye—Electricity at the National Swiss Exhibition: The Transmission of Power from Chevres-Geneva.—*Ibid.*, No. 21, p. 385 (I.).

Anon.—Statistics of Central Stations in Germany.—*Ibid.*, No. 22, p. 414.

DYNAMO AND MOTOR DESIGN.

G. Ossanna—On Synchronous Motors.—*E. T. Z.*, vol. 17, No. 20, p. 300 (S. I.).

J. Elster—A High-Tension Transformer without Oil Insulation.—*Beibl.*, vol. 20, part 5, 1896, p. 388.

A. Potter—On the Part played by Iron Cores in Dynamo-electric Machines: Remarks on the Note by Marcel-Deprez.—*C. R.*, vol. 122, No. 20, p. 1085.

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L. Lecornu—On a New Method of Regulating Motors.—*Ibid.*, p. 1188.

H. Leanté—Remarks on the Subject of the preceding Note.—*Ibid.*, p. 1191

Ch. Maurain—Polyphase Currents and Rotating Fields.—*Jour. de Phys.*, vol. 5, May, p. 204 (I.).

A. Bertier—Dynamo-electric Machines with Concentric Helices.—*Ecl. El.*, vol. 7, No. 19, p. 250 (I.).

TRACTION.

R. Ulbricht—The Prevention of Earth Currents from Tramway Conductors.—*E. T. Z.*, vol. 17, No. 19, p. 278 (I.).

A. Potier—On the Precautions to be taken against Electrolysis in the Laying down of Tramway Lines.—*Bull. Soc. Int.*, vol. 13, No. 128, p. 176 (I.).

P. Lauriol—On a Means of Diminishing Earth Currents due to Electric Tramways with a Rail Return.—*Ecl. El.*, vol. 7, No. 19, p. 241 (I.).

Anon.—Statistics of Electric Tramways in Europe.—*Ecl. El.*, vol. 7, No. 19, p. 264.

MAGNETISM.

L. Palazzo—Absolute Measurements of Earth Magnetism in Italy in the Years 1888 and 1889.—*Beibl.*, vol. 20, part 5, p. 485.

H. Nagaoka and E. Taylor Jones—On the Effects of Magnetic Stress in Magneto-Striction.—*Phil. Mag.*, vol. 41, No. 252, p. 454 (I.).

G. Moreau—On the Magnetic Torsion of Soft Iron Wires.—*C. R.*, vol. 122, No. 21, p. 1192.

W. de Nicolaieve—Electric Currents of Displacement and the Magnetic Induction of Iron under a Variable Condition.—*Ecl. El.*, vol. 7, No. 20, p. 289.

INSTRUMENTS AND MEASUREMENTS.

M. E. Maltby—Method for Measuring High Electrolytic Resistances.—*Beibl.*, vol. 20, part 5, p. 380.

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N. Kasaukin—On the E.M.F. of some Galvanic Elements.—*Ibid.*, p. 381.

E. Villari—A Torsion Galvanometer of Variable Sensitiveness: Measurements with same.—*Ibid.*, p. 386.

D. Mazzotto—New Method for the Measurement of Electric Refraction Exponents of Solid Bodies and Liquids.—*Ibid.*, p. 392.

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R. V. Picou—The Measurement of High Insulation Resistances.—*Bull. Soc. Int.*, vol. 13, No. 128, p. 172 (I.).

M. LAMOTTE—The Standard of Resistance of the Reichsanstalt.—*Ecl. El.*, vol. 7, No. 19, p. 245 (I.).

RICCARDO ARNO—A Modification of the Mascart Method for the Use of the Quadrant Electrometer.—*Ecl. El.*, vol. 7, No. 19, p. 280.

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TELEGRAPHY AND TELEPHONY.

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ANON.—The Telegraphs in the English Indies during the Year 1894–1895.—*Jour. de Tel.*, vol. 20, No. 5, p. 97 (S.).

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ELECTRO-CHEMISTRY.

A. HAGENBACH—Thermo-Elements from Amalgams and Electrolytes.—*Wied. Ann.*, No. 5, vol. 58, p. 21 (I.).

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F. STEINTZ—The Electro-chemical Effect of Röntgen Rays on Silver Bromide.—*Ibid.*, p. 448.

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ANON.—The Manufacture of Aluminium.—*Ibid.*, No. 22, p. 411.

ACCUMULATORS.

J. REYVAL—Boese Accumulators.—*Ecl. El.*, vol. 7, No. 20, p. 308 (I.).

STATIC ELECTRICITY.

Dr. W. KÖNIG—On Röntgen Lamps.—*E. T. Z.*, vol 17, No. 19, p. 303 (I.).

F. HARBORDT—On the Effect of Points.—*Beibl.*, vol. 20, part 5, 1896, p. 379.

P. CARDINI—On the Heat Phenomena of Discharges in Branch Conductors, and on the Resistance of Conductors.—*Ibid.*, p. 389.

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C. Fromme—On the Change of Electric Conductivity due to Electric Influences. —*Ibid.*, p. 96.

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N. Hesehus—On Electric Sparks over the Surface of Water.—*Beibl.*, part 5, vol. 20, p. 394.

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COMPANIES ACTS, 1862 TO 1893.

SPECIAL RESOLUTION

(*Pursuant to Companies Act*, 1862, *s.* 51.)

OF THE

INSTITUTION OF ELECTRICAL ENGINEERS.

Passed June 15th, 1896; confirmed July 6th, 1896.

At a SPECIAL GENERAL MEETING OF MEMBERS ONLY of the said Institution, duly convened and held at the Offices of the Institution, No. 28, Victoria Street, in the City of Westminster, on the Fifteenth day of June, 1896, the following **Special Resolution** was duly passed; and at a subsequent SPECIAL GENERAL MEETING OF MEMBERS ONLY of the said Institution, also duly convened and held at the Offices of the Institution, No. 28, Victoria Street, in the City of Westminster, on the Sixth day of July, 1896, the following **Special Resolution** was duly confirmed:—

RESOLUTION.

That the Regulations contained in the Articles of Association of the Institution be altered in the following manner, that is to say:—

By striking out the word "twelve" in the second line of the 36*th Article*, and substituting the word "fifteen."

By striking out the word "twelve" in the third line of the 38*th Article*, and substituting the word "fifteen."

By striking out the 40*th Article*, and substituting the following Article:—

"40. The following Members of Council, namely—the President, one Vice-President, "the Honorary Treasurer, five Members, and one Associate—shall be elected annually "by ballot. The President, one Vice-President, the Honorary Treasurer, five Members, "and one Associate shall retire annually, and, save as hereinafter provided, be immediately "eligible for re-election. Provided that no President, Vice-President, Member of Council, "or Associate Member of Council shall hold office in the same capacity for more than "three years in succession. Provided also that every Past-President shall be eligible for "election as an Ordinary Member of Council, but that whilst holding office as an Ordinary "Member he shall cease to be an ex-officio Member."

By striking out the 41*st Article*, and substituting the following Article:—

"41. The Auditors shall be elected annually by ballot, but shall be eligible for re-"election on the expiration of their year of office."

By the addition at the end of the 42*nd Article* of the following words :—

"but the Member or Associate so chosen shall retain his office so long only as the "vacating Member of Council would have retained the same if no vacancy had occurred."

By striking out all words after "Council" in the seventh line of the 43*rd Article* to the end of that Article, and substituting the following words :—

"At an Ordinary General Meeting held not less than twenty-eight days before the Annual General Meeting, the Chairman shall announce the candidates so nominated.

"Any two Members, supported by eight other Members, may thereupon nominate "in writing any duly qualified person to fill any vacancy by forwarding such nomination, "together with the written consent of such person to accept office if elected, to the "Secretary within seven days after such meeting.

"Thereupon a ballot list, containing the names of all persons duly nominated to fill "the vacancies on the Council, stating which persons are nominated by the Council, and "giving the names of the two Members by whom every other person is nominated, shall "be forwarded to the Members and Associates of the Institution not less than seven days "before the Annual General Meeting; and each Member or Associate shall be at liberty to "make a selection from such list, provided the number of names so selected shall not "exceed in any case the number requisite to fill the vacancies.

"Ballot papers shall be so marked and recorded as may be from time to time "determined by the Council."

By striking out the words from after the word "quorum" in the third line of the 47*th Article* down to the word "prescribe" in the fifth line of the same Article, and substituting the following words :—

"The Council may appoint Committees chosen from their own body, and Committees "for special purposes consisting of Members of Council and Members or Associates of the "Institution and others, with such powers as the Council may prescribe."

By striking out the words in the 48*th Article* from the beginning of the Article to the word "vote" in the third line, and substituting the following words :—

"48. Questions shall be decided at any meeting of the Council by the votes of the "Members present, each of whom shall, save as hereinafter mentioned, have one vote: "provided that, in the event of there being more than four Past-Presidents at any "meeting, the votes of the immediate Past-President and the four senior Past-Presidents "present and voting shall alone be counted upon any division; but the Chairman shall "have a casting vote."

By striking out the 50*th Article*, and substituting the following Article :—

"50. The financial year of the Institution shall end on the 30th September in each "year; and a statement of the funds of the Institution, and of the receipts and "expenditure during such financial year, shall be made, under the direction of the Council, "each year, and, after having been verified and signed by the Auditors and approved by "the Council, shall be laid before the Annual General Meeting next following."

By the insertion and addition of the following words to the 55*th Article*—viz., by inserting the words "upon the Accounts and" after the word "deliberate," and by adding at the end of the Article the words "at the Annual General Meeting, any business may be transacted of which notice in writing shall have been given to the Secretary at least fourteen days before such meeting."

A Special General Meeting of Members and Associates was held at the Offices of the Institution, 28, Victoria Street, Westminster, on Monday, July the 6th, 1896 Sir—DAVID SALOMONS, Bart., M.A., Vice-President, in the Chair.

The notice convening the meeting was taken as read.

The amended statement of accounts and balance-sheet for the year ending 31st December, 1895, a copy of which had been previously sent to all Members and Associates, was also taken as read.

The CHAIRMAN stated that the changes in the form of the statement of accounts and balance-sheet had been made by the Accountants under instruction of the Council, in order to meet the suggestions made at the Ordinary General Meeting of March 26th. He thought it, however, only fair to the Council, Finance Committee, the Accountants, and all concerned in making up the accounts, to say that the form in which they were originally presented was in accordance with the Articles of Association. A slight discrepancy, however, existed between the Memorandum of Association and the Articles of Association. By the former a statement of "receipts and "*expenditure*" was required. In the latter the term used was "receipts and *payments*." This had now been put right by the Special Resolution passed on June 15th and confirmed that afternoon, amending the Articles of Association. Sir David Salomons.

After one or two suggestions had been made which the Chairman said should receive due consideration before the next balance sheet was made up,

Sir HENRY MANCE moved—"That the Statement of Accounts "and balance-sheet for the year ending December 31st, 1895, as "this day submitted, be received and adopted.

Mr. W. E. LANGDON seconded the motion.

The motion, having been put from the chair, was carried unanimously.

The CHAIRMAN, in accordance with the notice, referred to the Building Fund. Sir David Salomons.

Sir David Salomons.

As regards the necessity of providing such a fund, he reminded the meeting that, although the Institution possessed the great advantage, through the extreme liberality of the Institution of Civil Engineers, of holding its meetings in their Lecture Hall, we had no right to look upon that privilege as a permanent one; and, moreover, that, as the hospitality of the Civil Engineers was extended to other societies, there was, of necessity, a limit to the number of meetings which they could permit us to hold on their premises. The Council had, as they knew, set apart out of the general funds a certain sum as a Building Fund, but they had no power to make such fund a permanent one, or to treat it as an absolute and distinct fund, and there was no power to make it cumulative by the accruing interest. This could only be done by consent of the Members and Associates, and he hoped they would see the wisdom of giving the Council that power now. It was also desirable from another point of view to make this fund a real and distinct fund. No one would be very likely to contribute to the fund so long as it existed only as a subdivision of, and liable at any time to be transferred back to, the general fund for expenditure on other objects. He trusted, moreover, that, in whatever directions further expenditure might be considered desirable in advancing the general interests of electrical engineering, we should be enabled annually to devote a certain part of our surplus to the augmentation of this fund. He then moved—"That the Building "Fund, which is now but a subdivision of the funds of the "Institution, be made a permanent 'Building Fund,' and that "the interest accruing from such fund or the investments thereof "be added to the fund from time to time."

The motion, having been seconded by Mr. THOMAS CUSHING, Member, was put from the chair and carried unanimously.

On the motion of Mr. LANGDON, seconded by Sir DAVID SALOMONS, a vote of thanks was unanimously accorded to Mr. J. W. Biggs, the Accountant, for the trouble he had taken in re-casting the statement of accounts and balance-sheet.

On the motion of Mr. SPAGNOLETTI, seconded by Professor HUGHES, the thanks of the meeting were unanimously accorded to Sir David Salomons for his conduct in the chair.

Sir D
Salon:

JOURNAL

OF THE

Institution of Electrical Engineers.

Founded 1871. *Incorporated* 1883.

Vol. XXV. 1896. No. 125.

The Two Hundred and Ninety-second Ordinary General Meeting of the Institution was held at the Institution of Civil Engineers, 25, Great George Street, Westminster, on Thursday evening, November 12th, 1896 — Dr. John Hopkinson, M.A., D.Sc., F.R.S., President, in the Chair.

The minutes of the Ordinary General Meeting held on May 28th, 1896, were read and approved.

The names of new candidates for election into the Institution were announced and ordered to be suspended.

The following transfers were announced as having been approved by the Council:—

From the class of Associates to that of Members—

Bernard P. Scattergood.

From the class of Students to that of Associates—

William R. Elliott.
Charles Alfred Hopton.
Robert John Strike.
Arthur Percy Strohmenger.
Leopold A. S. Wood.

Donations to the Library were announced as having been received since the last meeting from the Astronomer Royal, Mr. Evans Austin, Mr. F. W. Burstall, the Director-General of Telegraphs, India, Messrs. Macmillan & Co., Messrs. E. & F. N. Spon; and from Professor J. A. Fleming, Mr. R. Kaye Gray, Sir David Salomons, Professor Watkinson, and Mr. H. D. Wilkinson, Members; to whom the thanks of the meeting were duly accorded.

The PRESIDENT: I will ask the Secretary to read the address which was presented on behalf of the Institution to Lord Kelvin, on the occasion of the jubilee of his Professorship, and his letter in acknowledgment of it.

The SECRETARY read the address, and the letter of Lord Kelvin in reply, as follow:—

"*To the Right Honourable Lord Kelvin, D.C.L., LL.D., Past-*
"*President of the Royal Society.*

"We, the President, Council, and Members of the Institution "of Electrical Engineers, desire hereby to offer to your Lordship "our sincere and hearty congratulations on the occasion of the "Jubilee of your Professorship of Natural Philosophy in the "University of Glasgow.

"It will ever be a source of pride and satisfaction to this "Institution that one who occupies so pre-eminent a position in "the Scientific World, should have been its first President in "1889, besides having been an original Member, and President "in 1874, of the same Association when it existed under the "name of the Society of Telegraph Engineers.

"Not only have you contributed more than any other living "man to our knowledge of the laws of Nature, but you have "found time to perfect practical applications of Science where-"from every branch of the Electrical Engineering Profession has "derived special benefit.

"We desire, in conclusion, to express our fervent wish that "you may continue for many years to enjoy the blessings of

"good health, and that Science may still further benefit by your "labours.

(Signed on behalf of the Institution)

"JOHN HOPKINSON, *President.*
"F. H. WEBB, *Secretary.*

"*June*, 1896."

"THE UNIVERSITY,
"GLASGOW

"For the Address which I have had the honour to receive "from the Institution of Electrical Engineers on the occasion of "the Jubilee of my Professorship of Natural Philosophy in the "University of Glasgow, I desire to express my warmest thanks. "I value very highly the great honour which it has conferred on "me. The friendly appreciation of my scientific work contained "in the Address is most gratifying.

"I feel deeply touched by the great kindness to myself, and "the good wishes for my welfare, of which it gives expression.

(Signed) "KELVIN.

"*July 7th*, 1896."

The PRESIDENT: Our next business is connected with the election of the new Council. On the present occasion this will be done under a different set of articles from that under which it has previously been done, and it may be appropriate that I just shortly call attention to the arrangements as they now exist, this being the first time they come into force. I will read the article under which we proceed—it is the 43rd of the Articles of Association as at present constituted:—

The Council shall, previous to the Annual General Meeting in each year, prepare a list of Members whom they propose as suitable for the offices of President, Vice-Presidents, and Treasurer for the ensuing year. The list shall also contain the names of a sufficient number of Members and Associates to fill the vacancies in the Council, and whom the Council nominate as fitted to become Members of the Council. At an Ordinary General Meeting held not less than twenty-eight days before the Annual General Meeting, the Chairman shall announce the candidates so nominated. Any two Members, supported by eight other Members, may thereupon

nominate in writing any duly qualified person to fill any vacancy by forwarding such nomination, together with the written consent of such person to accept office if elected, to the Secretary within seven days after such meeting. Thereupon a ballot list, containing the names of all persons duly nominated to fill the vacancies on the Council, stating which persons are nominated by the Council, and giving the names of the two Members by whom every other person is nominated, shall be forwarded to the Members and Associates of the Institution not less than seven days before the Annual General Meeting; and each Member or Associate shall be at liberty to make a selection from such list, provided the number of names so selected shall not exceed in any case the number requisite to fill the vacancies. Ballot papers shall be so marked and recorded as may be from time to time determined by the Council.

You will observe that the intention of the alteration is to secure that the new officers and Members of Council of the Institution shall be those really elected by the majority of the members, and this alteration of the articles has been made entirely with that object. It now devolves upon you, after the list of the proposals of the Council have been read, to consider whether the names proposed are such as you would approve; if not, then any ten of you can agree together and can propose an addition to that list, and then the list will go before the general body of members for the purpose of election. I may say that it it is the desire of the Council that this altered article shall not be a dead letter; it is their wish that the members shall actively take advantage of it if they feel that they can do so with benefit. The intention in requiring ten members to sign the nomination paper is to secure that those who are put forward shall have a substantial following, and that, if put forward, they shall be put forward with a reasonable chance of election. You will also observe that it is requisite that the acceptance of the persons so nominated shall be obtained in writing. This is clearly necessary, because it is essential that, if any alteration in the Council's list be carried, it shall be effective, and shall not be rendered void by the gentlemen so nominated declining to act. Before reading the list of the names proposed by the Council, I should just like to remark upon one of the changes, viz., the retirement of Sir David Salomons from the office of Honorary Treasurer of the Institution. The Council view that retirement with very great regret Sir David Salomons, as we all know, has now for a

considerable time been a most admirable Treasurer to the Institution; and, although we have proposed a most able successor to him, we feel that we cannot have anyone who could better discharge the duties of this office than he has done. Of course you all know that Sir David Salomons has increasing duties upon him, and it is not unnatural that he should wish to be relieved of a portion of his work. At the same time, we wish it to be distinctly understood that the Council do feel very great regret in losing the advantage of his services as Treasurer.

The list is follows:—

MEMBERS NOMINATED BY THE COUNCIL FOR OFFICE IN 1897.

As President:

Sir HENRY MANCE, C.I.E., M. Inst. C.E.

As Vice-Presidents (4):

Remaining in Office.	ROBERT KAYE GRAY. Professor S. P. THOMPSON, D.Sc., F.R.S.
New Names.	Professor JOHN PERRY, D.Sc., F.R.S. JOSEPH W. SWAN, F.R.S.

Ordinary Members of Council (15):

Remaining in Office.	G. VON CHAUVIN. HENRY EDMUNDS. S. Z. DE FERRANTI. W. E. LANGDON. Professor J. A. FLEMING, M.A., D.Sc., F.R.S. DANE SINCLAIR.
New Names.	S. L. BRUNTON Professor J. A. EWING, F.R.S. W. P. J. FAWCUS. Major R. HIPPISLEY, R.E. E. MANVILLE. J. S. RAWORTH, M. Inst. C.E. HERBERT TAYLOR, M. Inst. C.E JAMES SWINBURNE, M. Inst. C.E. CHARLES HENRY WORDINGHAM.

Associate Members of Council (3):

For Re-Election. { Captain W. P. Brett, R.E.
H. W. Miller.
Sydney Morse.

OFFICERS NOMINATED BY COUNCIL FOR 1897.

As Honorary Auditors:

For Re-Election. { Frederick C. Danvers.
Augustus Stroh.

As Honorary Treasurer:

New Name. Professor W. E. Ayrton, F.R.S., Past-President.

As Honorary Solicitors:

For Re-Election. Messrs. Wilson, Bristows, & Carpmael.

On the suggestion of Mr. A. A. Campbell Swinton, it was agreed that on future occasions the notice of the meeting at which the list of the Council's nominees is to be announced, should state that such announcement would be made thereat.

The following paper was then read:—

THE TELEPHONE TRUNK LINE SYSTEM IN GREAT BRITAIN.

By J. Gavey, Member.

Mr. Gavey In the early days of the telephone, whilst various local systems were being developed, and before the idea of providing trunk lines between neighbouring towns had been matured, the question of long-distance telephony received careful consideration. The pioneer experimenters at once found themselves face to face with the numerous troubles, generally ascribed to induction, which rendered speech impossible on single-wire circuits during the busy telegraphic hours of the day, and very difficult on such metallic loops as could be made *up from* existing telegraph circuits. In a paper read before the

Physical Society on January 19th, 1878, Mr. Preece described the various causes to which these disturbances were due, and he suggested a method of screening a single-wire circuit both from electrostatic and electro-magnetic induction. He also pointed out the true solution of the difficulty, *i.e.*, the use of metallic circuits for telephonic purposes—a practice adopted by the Post Office from the first, and one that has been consistently urged as necessary, if a really efficient telephonic service is sought. Professor Hughes continued the subject in his paper, read before the Institution on March 12th, 1879, in which he described the method of revolving the two wires of a metallic loop to obtain a practical balance. In a subsequent paper read before the British Association in 1885, Mr. Preece pointed out the merits of copper as a conductor, and in 1887 he enunciated the K R law in a paper read before the Royal Society. Mr. Gavey.

The following are the theoretical principles involved in the erection of balanced telephone circuits:—

When two complete circuits, either wholly metallic or partly metallic and partly earth, are placed in juxtaposition, each is subject to the following interferences:—

FIG. 1.

1. Induced currents due to electro-magnetic induction.

If two circuits or portions of circuits be contiguous to one another, then, on establishing a current in No. 1 circuit (Fig. 1), a certain number of magnetic lines of force cut No. 2, and a current of brief duration is observed in the latter; and, disregarding direction for the present, corresponding results are observed on the increase, the cessation, or the diminution of the current in No. 1.

2. Induced currents due to electrostatic induction.

Electrostatic induction induces a momentary redistribution

Mr. Gavey. of electrification in neighbouring wires, the result being the passage either transversely or longitudinally of currents of short duration. The cessation of the primary current results in momentary induced currents in the reverse direction to the former.

3. If a single wire with an earth return be used, in addition to the above results, leakage from the earth plates and stray currents from other electrical circuits, or from the earth itself, enter the circuit. This aspect of the case may, however, be disregarded at present, for in practice trunk circuits always consist of metallic loops.

If we consider the combined effects of electro-magnetic and electrostatic induction from a single-wire circuit with an earth return—first on a similar circuit, and then on a looped or balanced circuit—we get the results, on the closing or the increase of the current in the primary circuit, which are illustrated in Fig. 2, where the continuous arrow, ———>, shows the primary current, the dotted arrows, ········>, the induced current due to electro-magnetic induction, and the double-barbed arrows, ········>>, that due to electrostatic induction.

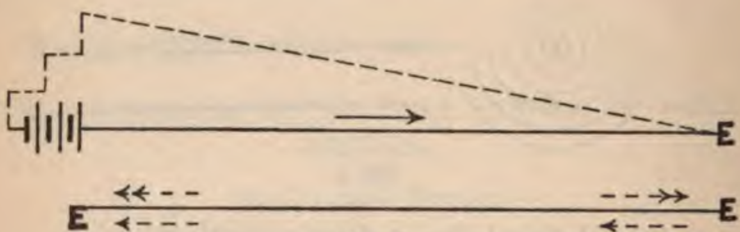

Fig. 2.

The reverse results are observed on the breaking or diminution of the current in the primary circuit. It will be noticed that in unbalanced earthed circuits the current due to electro-magnetic induction is opposite to that in the primary on closing the latter, whilst that due to electrostatic induction is in the same direction as the electro-magnetic induction current at the battery end, and in the opposite direction at the far end. Thus, at one end of such a circuit a disturbance due to the sum of the

two currents is observed, whilst at the other end one due to the difference alone is seen. Mr. Gavey.

In the case of the balanced circuit, if all the conditions for silence indicated below are realised, the result of electro-magnetic induction is that similar potentials are developed along both sides of the loop; the single-barbed dotted arrows (Fig. 3) showing the direction only that the current would flow in either branch if, owing to defective balance, the potential in the other were reduced.

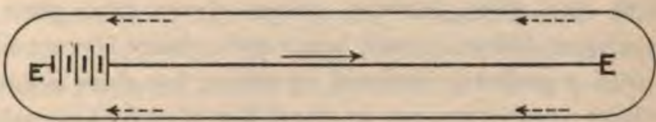

Fig. 3.

The electrostatic effect will depend on the condition of the circuit. If the primary or disturbing circuit be perfectly insulated, and if it be disconnected at the far end, or if it be terminated in a condenser, and if the insulation of the secondary be extremely high, minute currents cross the conductor transversely so as to effect the redistribution illustrated by + and – signs in Fig. 4;

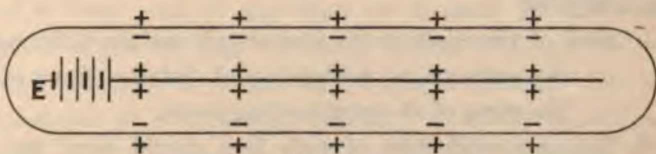

Fig. 4.

no currents in a longitudinal direction being developed. If, however, the disturbing or primary circuit be to earth, or if it consist of a neighbouring loop, minute longitudinal currents in the

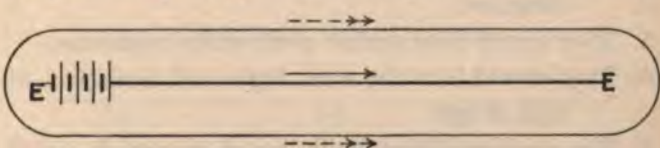

Fig. 5.

direction shown by the double-barbed arrows in Fig. 5 actually circulate.

Mr. Gavey. The combined effects on a balanced loop with the resultant earth in the centre of each wire are illustrated in Fig. 5A.

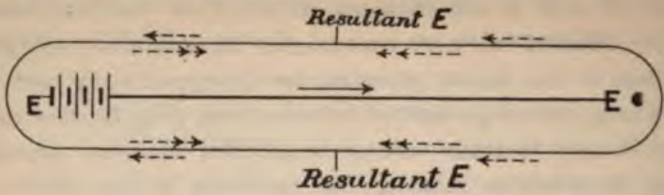

FIG. 5A.

With open wires, however, leakage always takes place over the insulators; hence a much larger static charge is accumulated than with a perfectly insulated secondary, the above conditions are subject to variation, and an actual flow of current in each arm takes place, the direction of which is dependent on the distribution of the leakage, or the position of the resultant earths.

The conditions which are necessary to obviate interference, due to the above causes, between two neighbouring circuits, one of them at least being a metallic loop, are the following. For practical purposes each circuit, which has great length compared to its depth, is considered to consist of two sides alone, the ends being negligible.

1. Each of the wires of one loop should maintain throughout the same or an average equal distance from each of the wires of all neighbouring loops.
2. The two conductors of each loop should be of the same material.
3. They should have the same conductivity.
4. Each half of the circuit, including apparatus in direct circuit, should possess the same coefficient of self-induction.
5. They should have similar electrostatic capacities.
6. They should have the same degree of insulation, whether high or low.
7. The resultant faults due to loss of insulation should be in the centre of each wire of the loop; but if not there, each should occupy similar positions at equal distances electrically from the extremities.

The necessity for the above conditions is obvious when it is Mr. Gavey. considered that the induction from all neighbouring wires causes constant variations of potential and local currents to circulate along each wire, which must not affect the telephones at either end. Thus, any difference in electro-magnetic inertia, resistance, or capacity between the two arms of a circuit will cause currents to traverse the terminal telephones. With a symmetrical circuit these two telephones occupy absolutely neutral positions at opposite extremities of the circuit, and, if each telephone be wound differentially, and be perfectly balanced, earth may be applied at the centre of each instrument without creating disturbance; whereas, if earth be applied at any other point in the circuit, even at the point where the line wire joins the telephone, the disturbance from neighbouring wires becomes at once marked. Again, any two points of equal potential in the circuit can be bridged without creating disturbance, which means that any number of telephones or indicators may be placed in multiple arc across the balanced wires without upsetting the balance.

Conditions 1 to 5 are readily met, and, once attained, they are stable. No. 6 is more difficult to ensure, for the insulation of either arm of a loop may at any time be lowered by innumerable accidental causes, so that the most careful attention to maintenance is necessary to remove this source of trouble. No. 7 is at times a source of considerable difficulty, especially in the case of telephone trunks erected on poles carrying high-speed Wheat-

FIG. 6.

stone wires, when the latter are worked with shunted condensers. Thus, in Fig. 6, with the resultant earths at points 1, points 2, or

Mr. Gavey. at other symmetrical positions, the circuit is silent; but with positions 3 disturbance becomes evident, for the currents entering at these points traverse the telephones in establishing the electrostatic redistribution.

Normally, the currents due to electro-magnetic induction would be more considerable than those arising from electrostatic induction in a single-wire circuit with an earth return. Experiments made between Newport, Cardiff, Swansea, and Haverfordwest, between ordinary parallel wires, under certain conditions, gave the ratio between the two as 9,096 : 306 at the battery end, and 9,096 : 153 at the far end; and the disproportion would be still more marked in a loop. Notwithstanding these facts, it is far easier with open wires to balance magnetic than static disturbance, as the conditions necessary to ensure the former are more readily controlled. This is illustrated by a simple experiment with a high-speed transmitter working an ordinary telegraphic circuit, attached to the same poles as a balanced loop. With the telegraphic circuit to earth, in the usual manner at the far end, and a current of 30 or 40 milliamperes, the balanced loop may be practically silent. Add a shunted condenser, or disconnect the far end of the telegraph circuit, and disturbance may become most marked. The effect is much greater than would be accounted for by the mere fact that in the extreme case of the far end being disconnected the average potential of the disturbing line is as a maximum doubled throughout. The fact is that when the primary circuit is disconnected, or a shunted condenser is fitted at the extremity, the rise and fall of potential is practically instantaneous, and the effect on the telephone circuit is at its maximum; whereas with the conditions for simple working the electro-magnets of the receiving instrument cause a flattening of the current-curve, and the rise and fall of potential is too slow to injuriously affect the telephone.

The methods of construction of telephone trunk lines differ but slightly from those adopted in the erection of ordinary telegraph lines, the principal difference arising from the necessity for providing the balanced circuits referred to above.

Taking first the simple case of two contiguous metallic circuits,

if they be arranged so that the two arms of each loop are at diagonally opposite angles of a square (Fig. 7), then the condition Mr. Gavey.

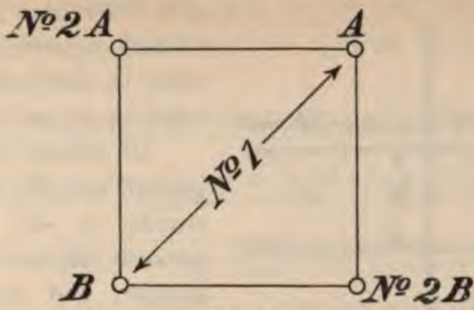

FIG. 7.

No. 1 is observed, and the circuits are balanced for distance, whether the wires are run straight or whether they revolve; and in a similar manner a loop on a horizontal arm (Fig. 8) is balanced against a single wire on a saddle with an earth return, so long as the single wire is at the apex of an isosceles triangle of which the loop forms the base. With this exception, to obtain a balance between one loop and a second circuit external to it, whether metallic or with earth return, the wires of each loop must revolve uniformly the one round the other. In underground work this revolution is a uniform spiral, but with open work the wires simply change their positions regularly on each successive pole.

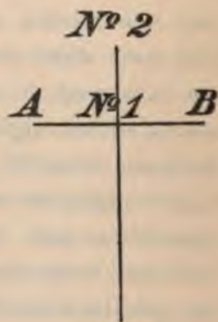

FIG. 8.

In England the method adopted is almost uniform, and it consists in continuous changes of position, every wire being moved transversely at an angle of 90° at each pole, so that a complete revolution is effected in every four spans. Other methods of crossing have been adopted on the Continent, but the above is perhaps the most simple way of achieving the end in view. In some cases the wires are run parallel and crosses introduced at intervals to obtain an approximate balance.

The present practice is to erect four wires on arms 48 inches long, divided as shown in Fig. 9, the arms being fixed on the poles

Mr. Gavey. 12 inches apart from centre to centre. Thus two arms provide space for four metallic circuits, the four wires on each side of the pole forming a section of a 12-inch square, the diagonal wires in these squares being taken up by each circuit.

Fig 9.

Of course, as previously pointed out, the two diagonal circuits in one square are perfectly balanced against one another, and therefore free from mutual disturbance; but in dealing with a large number of telephone loops, if the relative average distance between each of the two wires of any one circuit, say, in the right-hand square and those of the two wires forming each circuit in the left-hand square be measured, it will be found, when all wires have the same twist, either right or left-handed, that the average distances between wires of the circuits, the diagonals of which are at right angles to one another, are equal, whilst those that are parallel are not. If one square has a right-hand and the other a left-hand twist, then the converse is true—viz., the circuits that are parallel at each pole are balanced, and those that are transverse are not. It is found in practice that disturbances that arise between neighbouring twisted circuits can be eliminated by crossing systematically. Thus, dealing with a number of circuits on one route, the four wires forming the first square may be revolved uniformly throughout. The next four have the A and B wires of each circuit crossed eight miles from the starting point, and at intervals of eight miles onwards. The third group have the first cross four miles from the former point, then the remainder of the crosses succeed at intervals of eight miles. The wires of group four are crossed throughout at intervals of four miles. Those of group five have the first cross two miles from the terminal, then the remainder of the crosses at four-mile intervals. Group six is crossed at

intervals of two miles. It will be observed, on examination of Fig. 10, which illustrates the arrangement, that each circuit is balanced against all the neighbouring ones; and by this simple method it has been found possible to establish a series of wires absolutely free from overhearing. Mr. Gavey.

Fig. 10.

Hard-drawn copper wire is universally used for trunk lines. Its high conductivity, its freedom from electro-magnetic inertia, its great strength, and its durability, fit it eminently for this class of work. The trunk lines erected by the Post Office vary in gauge from wires weighing 100 lbs. per mile to wires weighing as much as 800 lbs. per mile. The use of such heavy wire as the latter was a subject of much controversy when the present policy of the Department was decided upon, but the results obtained have fully justified the action taken by Mr. Preece. There is, of course, no doubt that with overhead wires pure and simple it would have been quite possible to speak from one end of Great Britain to the other with smaller wires than those actually used for the "back-" bone system," but many critics appear to have overlooked the fact that this system was designed with a view to provide for conversation through submarine cables, and through city underground work between London, Belfast, Dublin, and the Continent on the one hand, and the great provincial business centres on the other.

The resistances and the inductive capacity of the various overground wires used in practice are as follows:—

Lbs. per Mile.	Resistance. Standard Ohms.	Capacity to E.	Capacity, Wire to Wire.
100	8·782	0 0144	0·00864
150	5·854	0·0147	0·00882
200	4·391	0·0150	0·00900
300	2·929	0 0153	0·00918
400	2·195	0·0156	0·00936
600	1·464	0·0158	0·00948
800	1·098	0·0160	0·00960

Mr. Gavey. It will be observed that with the standard distances at which the wires of a loop are erected in this country the capacity, wire to wire, is 0·6 that of the wire to earth.

The use of underground wires for trunk lines was utterly impracticable so long as gutta-percha, india-rubber, and other kindred materials only were available for insulating purposes. The introduction of what is practically an air-space cable by the use of paper insulation appears to offer the solution of a difficulty looming in the immediate future, namely, the finding of space for the numerous wires, both telegraphic and telephonic, which will be required between busy centres. Unfortunately, the need for two wires for each telephone circuit results in the rapid filling up of all aerial supports; and the undesirability of overcrowding poles with wires in a climate like ours, subject to snowstorm interruptions, is obvious.

Hitherto, the capacity of underground conductors, which roughly equalled 0·3 of a microfarad per mile, seriously limited the use of subterranean conductors. The capacity to earth of paper cables has already been reduced to a figure varying from 0·06 to 0·08 microfarad per mile with small conductors weighing 20 to 40 lbs. per mile; and although these are not well adapted for long trunk circuits, their use for relatively short circuits will soon become general. For heavier conductors, weighing 100 or 150 lbs. per mile, the capacity to earth is about 0·1 microfarad per mile.

The growth of the trunk system of this country, at first slow, has received a remarkable impetus since the Post Office has determined on its present policy. Mr. Gavey.

The first trunk circuit in Great Britain was erected between Cardiff and Newport, and was opened in August, 1881. Shortly afterwards a second loop was erected. Next followed two metallic circuits between Liverpool and Manchester, opened January 27th, 1882; and in May, 1883, two trunk circuits were erected between Newcastle and Sunderland.

The system grew slowly, as the local telephone exchanges increased in size, until the year 1884, when the various telephone companies were authorised to erect trunk wires between any of their exchanges. They then commenced the erection of a trunk wire system which has now been acquired by the State.

At the end of the year 1895, the mileage of telephone trunk wires in Great Britain and Ireland, actually complete or in course of completion, had reached the following figures:—

	Miles.
Post Office system	20,522
National Telephone Company's system ...	28,999
Giving a grand total of	49,521

Further and rapid growth may be confidently expected, so that the present mileage will soon be largely exceeded. Every great town in the country is, or will be, connected with the telephone trunk wires of the State; and it is probably not unsafe to predict that within the course of a few years practically the whole of the commercial business of the country will be transacted by telephone. In neighbouring manufacturing and commercial districts this condition of things has already been nearly attained.

The method of working the telephone trunk system of the country, with due regard to all the interests at stake, has been a matter of careful consideration on the part of the Post Office Department in conjunction with the responsible officers of the Telephone Company. The acquisition of the whole of the trunks by the State involved the application of the maxim that "no "favour should be shown and no priority given," but that all the

Mr. Gavey. Majesty's subjects, whether subscribers to exchanges controlled by the Department or by private companies, or non-subscribers using call offices, should be placed on an equal footing, and have an equal right to the use of the trunks in the order of application. This involved as a first step the termination of the trunk circuits at the post offices of the towns served—a course which has accordingly been followed. Every such post office is fitted with one or more silence cabinets at the public counter, where communication can be obtained through the switch-room with the trunks serving the town, and through them with any part of the country. Although, however, communication from public silence cabinets, in the manner provided for, is at times of considerable convenience to individuals, the vast mass of the telephone trunk traffic must obviously emanate from and be for subscribers permanently connected with local exchanges; and accordingly the important problem which had to be solved was the working out of a system that would provide for establishing the most facile and rapid means of communication between the trunk circuits of the Postmaster-General and the subscribers to local exchanges, whether those of the Post Office itself or of the company. As the majority of the local exchanges are situated in the company's buildings, at a distance from the respective post offices, it would at first sight appear as though the concentration of the trunk circuits in the latter would introduce undesirable delay in manipulation; but on examination of the problem it becomes evident that this is not necessarily the case. At all large offices the separation of the trunk system from the local switch was long ago effected; and although the local subscribers' wires were generally multipled on the trunk switch-board, a subscriber's request for trunk line service was necessarily first communicated to the operator in charge of the local section, and, as it was impossible to arrange for every such local operator to have direct access to the trunk circuits, the request had to be conveyed by telephone to a recording operator, who first registered the want, after which the ticket containing the details was passed by a collector to the trunk operator in charge of the particular circuit wanted. Thus, whether, as was usually the case at the company's offices, the trunk switch

was in the same room as the local switch, or, as occasionally Mr. Gavey happened, in an adjoining one, the same number of operations would be necessary in either case. Now, instead of the trunk switch being in the adjoining room, it is in another building in a neighbouring street, and, so far as the actual mode of transmitting information as to a subscriber's requirements is concerned, the operations are the same in number and character in both cases.

The general system adopted is as follows:—All the trunk circuits are terminated at the respective post offices. Connection between the trunk and the local subscribers' switches is established by means of "junction circuits." For each trunk circuit one junction is provided to the local post office switch, and one to the company's principal exchange switch These junctions are used solely for switching.

For conveying instructions, call or service circuits are established in the ratio of two circuits to each local switch for every 20 or less number of trunks. Half these circuits, known as "up" call circuits, connect the local switches with the recording tables, and they terminate in headgear telephones which are worn continuously by the ticket operators. The other half, known as "down" call circuits, serve to connect successive groups of 20 trunk jacks direct with the switches of the local subscribers, and they likewise terminate in headgear telephones.

At the smaller offices, where a few trunk circuits only exist and the traffic is but slight, the call wires are fitted with indicators; and at the larger offices the call wires are terminated on indicators during the slack periods, as it would obviously be absurd to retain an operator listening continuously for a few intermittent calls.

The method of working is, briefly, as follows:—A demand for a trunk call is conveyed to the local switch operator; the latter at once, without initiatory ring or signal, transmits the request to the recording operator, who enters the particulars on a ticket, which is then timed in telegraphic code and sent to the trunk section affected. It may thus be said that a local subscriber's want is immediately made known to the trunk operator at the neighbouring post office; although the actual time of putting

Mr. Gavey through and the commencement of conversation depend, of course, on the number of prior calls, and the time lost in obtaining the distant subscriber's attention.

When the call matures—*i.e.*, when the trunk circuit is free, or previous calls have been disposed of—the trunk operators at each extremity come in on the "down" call circuits, and request the junction operators to join specified junctions through to the subscribers who are wanted. This done, the trunk operators then ring up the subscribers, and on receiving replies they connect them direct to the trunk circuit.

Stripped of all technicalities, the method of working is, briefly, as follows:—

A subscriber, say 100, in a town "A," wishes to communicate with one, No. 200, in a town "B."

The former calls his local exchange, and expresses his wish to the local operator, then hangs up his telephone. This request is at once transmitted on the "up" call wire to the ticket operator at the post office, where it is recorded on a white numbered ticket, which is timed and placed on the trunk switch.

In proper turn with others the ticket is dealt with thus:— The trunk operator at "A" transmits the request to the trunk operator at "B," who enters details on a pink ticket. The "A" trunk operator then comes in circuit on the "down" call wire, and asks the junction operator to connect subscriber 100 to junction, say 4, at the same time inserting the necessary pegs in junction 4 and in the trunk. The junction operator ascertains in the usual manner if the subscriber is disengaged, and, if so, she makes the necessary connection, advising the Post Office operator of the fact. The latter then rings up subscriber 100, and tells him he is through to 200. At the same time the trunk operator at "B" is getting through to and calling 200 in a similar manner, and when both subscribers answer their calls they find themselves in communication with one another. Although the detailed description of the operations may appear complicated, the facilities for communication between the trunk and the junction operators are such that the brief instructions that are necessary are conveyed in a few seconds, and the loss of time in manipulation by skilled operators is insignificant.

The above describes the ideal condition of things. Unfortunately, in many cases, subscribers fix their telephones in out-of-the-way localities, and leave them in charge of office boys, who frequently regard them as toys rather than as a serious means of effecting important correspondence. In these cases the attention given is often bad, much time is wasted in ringing even before an answer is obtained, and more time is lost in fetching a responsible person to the instrument to deal with the matter in hand. In the meantime one of the subscribers is probably standing at his telephone unconscious of the cause of delay, but anathematising the Post Office, the Telephone Company, and all connected therewith, and not unfrequently he concludes with a series of bitter complaints addressed to the local Press. Mr. Gavey

The obvious remedy for this undesirable state of things is for firms who have a considerable amount of telephone correspondence to provide two or more local connections, one of which should be rigidly reserved for trunk work. The telephone in connection with the latter should be fitted in the office of a responsible member of the firm.

In designing the apparatus necessary for working the Department's trunk circuits in accordance with the foregoing principles, innumerable matters of detail had necessarily to be considered, amongst the more important being the following:—

1. The capacity of the separate sections of a trunk switch, and the provision for growth and extension at each office.
2. The working capacity of the operators—*i.e.*, the number of trunk circuits each could manipulate satisfactorily and without delay during the busiest periods of a working day.
3. The signalling and calling arrangements both for trunk and junction circuits.
4. Facilities for through trunking—*i.e.*, connecting two or more trunk circuits at intermediate offices to provide communication between towns not directly connected.
5. General details of switch and transfer on through trunking sections.

Mr. Gavey. 1. *Capacity of Sections.*—In dealing with this branch of the subject, requirements of very wide diversity had to be provided for, ranging from cases of offices with a single trunk circuit only to those with 200 or more circuits. Again, the growth of the system, which in certain localities will unquestionably be rapid, had to be considered, and it was obviously desirable to adopt arrangements of such a character that even in the case of abnormal increase there would be no necessity for any material modification of the apparatus already joined up. To meet these requirements it was determined to adopt as a unit a section complete in itself, containing all the necessary jacks, cords, indicators, keys, &c., for a certain number of trunks, and to provide as many of these sections as were needed at each office. Each such section is of such a size as to provide space and work for one operator in busy times, although in slack periods the whole of the apparatus on three sections is within the reach of, and can be worked by, a single individual. Thus, an office with one or two trunk circuits is fitted with one section; and, briefly, as many sections as are necessary to provide for the existing number of trunks and for a reasonable growth are fitted up to start with. Subsequent growth is met by the addition of the requisite number of sections without serious modifications of the existing ones; a mere redistribution of the position of the circuits to facilitate the traffic, together with the undermentioned slight alterations in the case of minor offices, being all that is necessary.

Although switch sections of uniform size and pattern have been adopted, the requirements at the smaller offices are, of course, not exactly of the same character as at the larger ones, therefore three types have been provided, respectively known as "A," "B," and "C" sections.

Small offices with less than three trunks are provided with an "A" section; offices with from three to 10 trunks are fitted with "B" sections; offices with more than 10 trunks with "C" sections.

These sections differ only in the minor details of the arrangement of junction circuits, the presence or absence of transfer

circuits, referred to later on, and other small points. The principle of working is the same throughout. Mr. Gavey.

2. The number of trunk circuits on each section is practically determined by the manipulating capacity of an average trunk operator. If the latter be unduly burdened with work, delays arise in establishing communication, the idle periods on each trunk during busy hours become serious, more circuits are necessary for the transaction of business than would otherwise be required, and, as a consequence, there is a waste of capital and of maintenance charges. On the other hand, if the trunks are over-staffed, loss arises in clerical wages. The latter is, perhaps, the less serious item of the two, more especially when long and costly trunk circuits are in question.

As the result of the general experience of telephonic working in this country, and after careful consideration of the whole question, it was concluded that, as an average, a fairly skilled operator should work five trunk circuits with facility and without delay. Accordingly the unit section was designed to accommodate this number.

3. *Signalling, &c.*—In the very earliest days of telephone exchange working Mr. Preece introduced an automatic system of signalling, which was so designed that the mere act of removing a telephone from its support announced a call by the dropping of a shutter in the exchange, whilst the restoration of the telephone to its normal position caused a current to be sent to the exchange which indicated, by a visible signal, the completion of the conversation, and the necessity for withdrawing the connecting pegs and restoring the shutter. This system became general in all Post Office exchanges, both on local and, in a modified form, on trunk circuits.

In ordinary methods of open-circuit trunk working the switch operator first inserts a peg in the trunk jack, then rings up her correspondent by means of a separate key or press button. The reverse operations are repeated at the close of the transactions, and if several trunks are connected at intermediate points these operations have to be repeated on each trunk.

With an automatic system of signalling the insertion of the

Mr. Gavey. peg indicates a call at the distant office, and its withdrawal indicates the close of the transaction. These signals are automatically repeated through any number of independent trunks which for the time being may be joined up to form one circuit.

The conventional signals which have been adopted by the Department are the following:—

Indicator needle to the right	...	Line disengaged.
,, ,, ,, left	...	Calling.
,, ,, vertical ...	...	Line engaged.

The line indicator is a combination of a polarised relay, the electro-magnets of which are placed horizontally, with an indicator needle in front of the poles.

Normally, when the switch is fully manned, the traffic is regulated by the movements of the indicator needle alone, but for slack periods and at night the relay is brought into use to repeat calling signals through a local circuit by means of a bell or a buzzer. These bells are cut out of circuit by suitable switches during the day. The manner in which the signals are transmitted is illustrated in Fig. 11.

It will be observed that in its idle position the line terminates on the indicator relay, in circuit with which is a battery of six cells known as the "permanent current line battery." A second battery of three cells, known as a "permanent current local," is joined up through a 350-ohm resistance and through the right-hand half of the relay electro-magnet in such a manner as under certain conditions to reverse the polarity established by the line battery.

The distant end of the line being terminated in a similar manner, the two positive poles of the respective line batteries are normally connected to the "A" line, and the two negative poles through relays to the "B" line; thus, if the insulation is reasonably high, no current flows from either end, and these batteries have no effect on the relay indicators. On the other hand, the local permanent current batteries send currents through the right-hand half of each relay electro-magnet, the effect being to deflect each indicator needle to the right.

If the distant operator now inserts a peg, she disconnects her

indicator relay with its opposing batteries, and substitutes the Mr. Gavey. resistance of her local apparatus alone. The permanent current

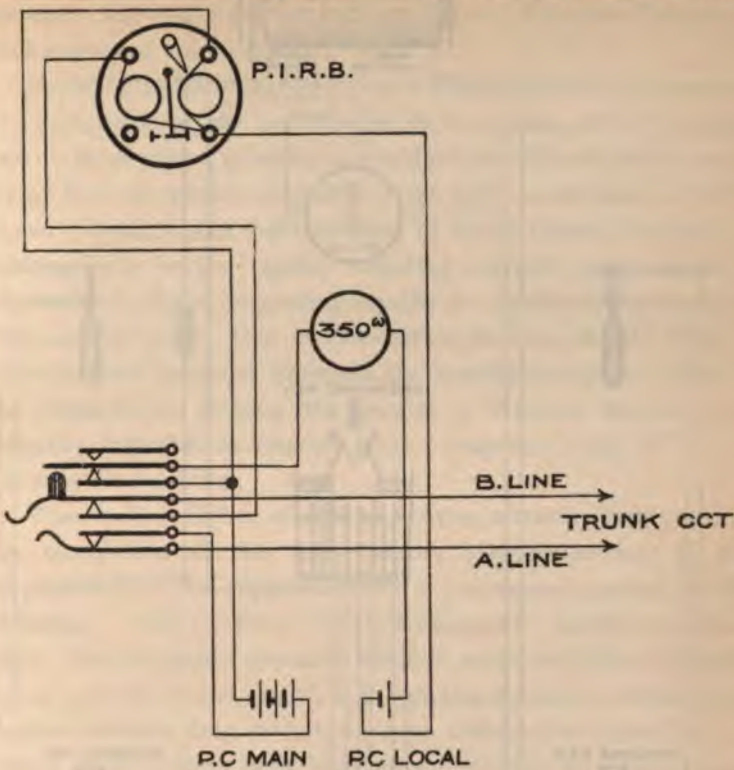

Fig. 11.

line battery current at the near end then flows with a reduced electro-motive force due to the effect of the local battery, but in the opposite direction to the local current through the right-hand coil, and with the added electro-motive force of the local battery through the left-hand coil of the relay. The polarity of the electro-magnet is reversed, and the needle deflected to the left.

On the insertion of a peg in the home jack to respond to the call, that indicator is also cut out of the line circuit, the local and line signalling batteries are disconnected, and the indicator needle becomes vertical.

Ringing keys are likewise provided; one set, with black press buttons, being connected to batteries; the second set, with red

Mr. Gavey press buttons, being joined to a small alternating dynamo, a pole

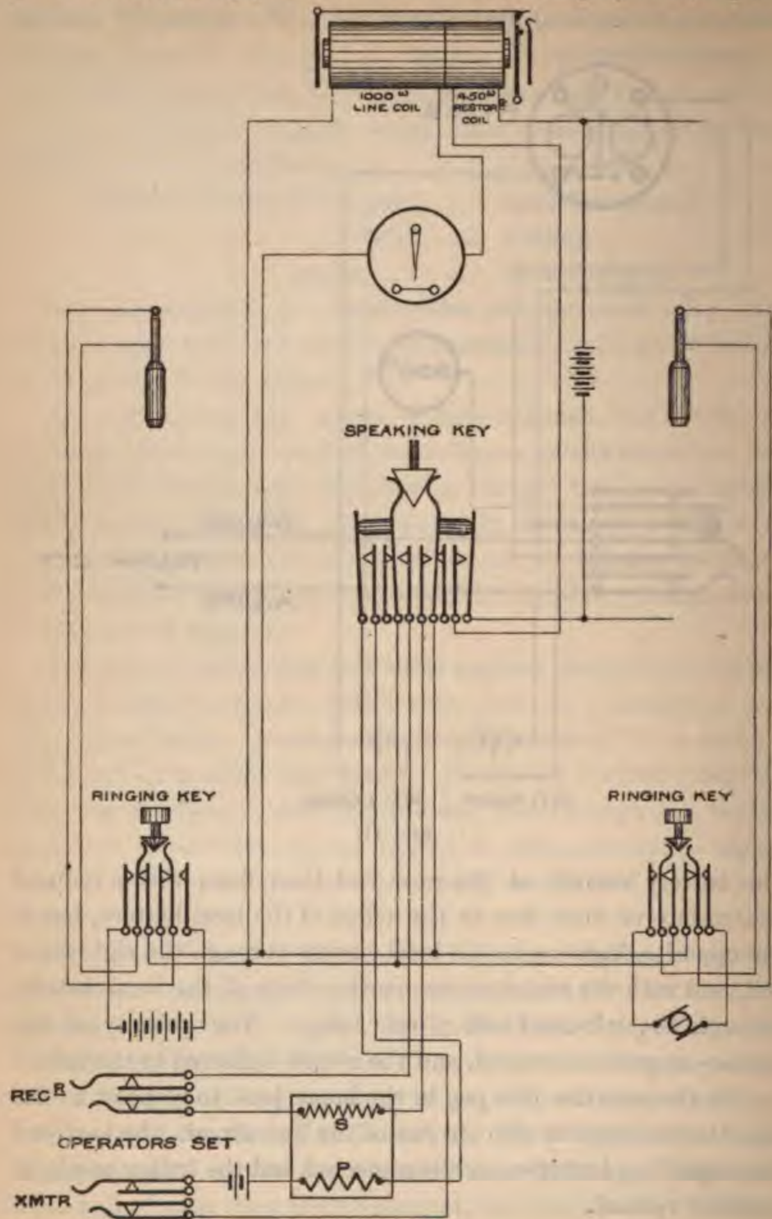

FIG. 12.

changer, or a magneto ringer, according to the size of the office. The connections are illustrated in Fig. 12.

The black keys are used for ringing up subscribers to Post Office exchanges, and for occasional use on the very long trunk circuits; the red keys for calling up the National Company's exchanges and subscibers. Mr. Gavey

Separate indicators are provided in the switch cords to announce the completion of the conversation or the "ring off." There are two of these joined in series and bridged across each pair of cords, which form an electro-magnetic shunt with a resistance of 2,000 ohms. Owing to the self-induction of these shunts, they act as choking coils to the rapidly vibrating currents when speech is transmitted, whilst responding readily to permanent currents or slow alternations. One of the indicators is a simple form of galvanometer designed to repeat the automatic signals in use on the Department system, the second a Western Electric self-restoring indicator to respond to the magneto "ring off" of the company's subscribers.

When a Post Office subscriber is using a trunk circuit, and on the completion of his conversation, the restoration of the telephones to their supports sends a permanent current to the exchange. This deflects the galvanometer needle described above; the exchange operators at both ends withdraw the pegs; and, if only one trunk circuit is in use, the indicator relays, which are now brought into circuit, are both deflected to the right. If several minor trunks have been joined through at various intermediate points, the line permanent currents from the terminal offices deflect the needles of the telephone galvanometers at the intermediate points where connections have been effected. The operators, without further inquiry, withdraw the pegs, and the normal condition of things is restored.

When a trunk is in use by a subscriber to the National Telephone Company, the operators are dependent on the business-like aptitude, or otherwise, of the subscribers for the "ring off." Should the latter fail to give the requisite turn of the handle to his magneto ringer, the Post Office operators have to come into circuit at the expiration of the allotted period to inquire if the conversation is finished, before withdrawing the pegs.

Should a prompt reply not be given to an automatic call on a

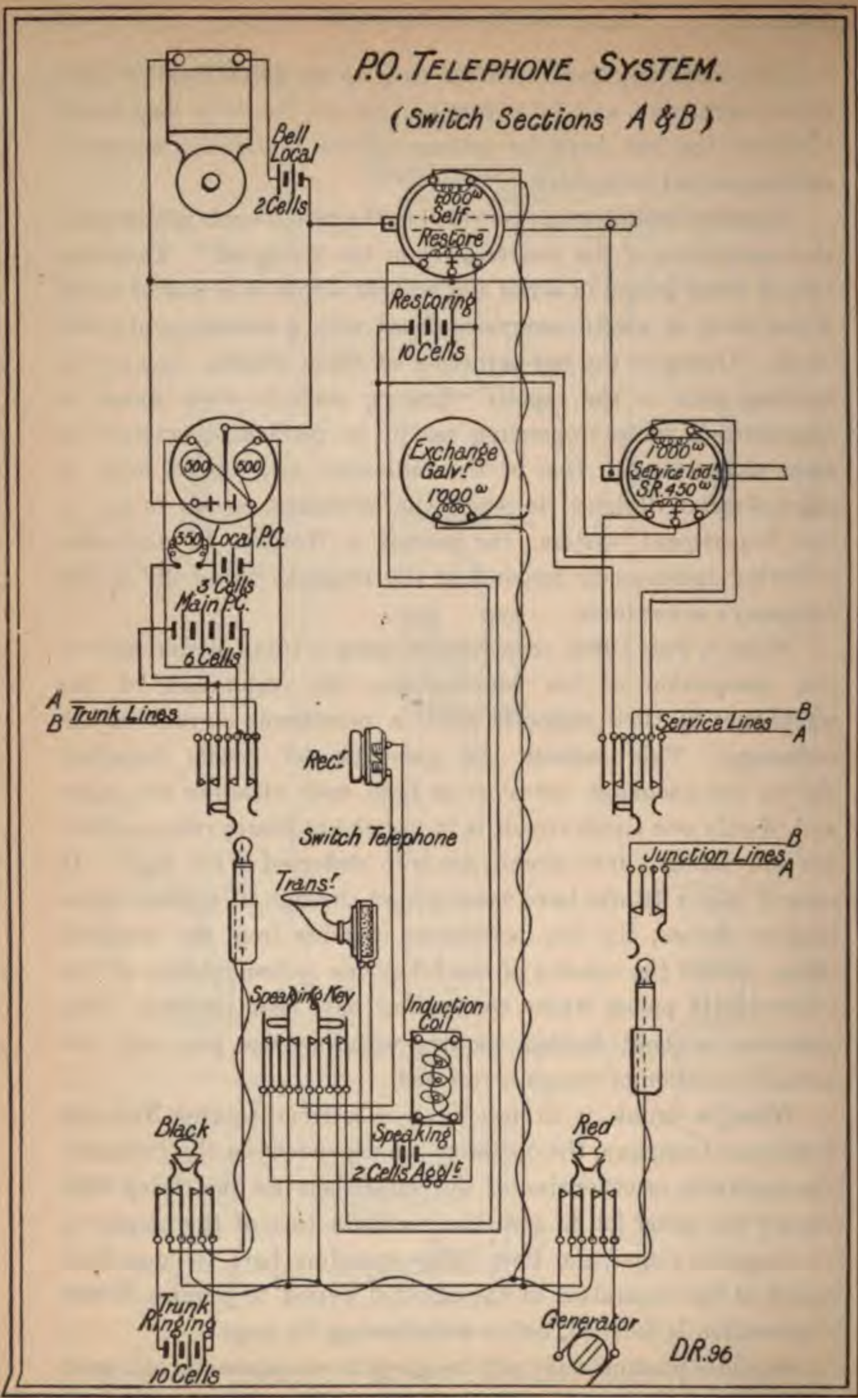
P.O. TELEPHONE SYSTEM.
(Switch Sections A & B)
Bell
Local
2 Cells
1000ω
Self
Restore
Restoring
10 Cells
Exchange
Galv.
1000ω
1000ω
Service Ind.
S.R. 450ω
500
500
550
Local P.C.
3 Cells
Main P.C.
6 Cells
A
B
Trunk Lines
Service Lines
B
A
Rec.
Switch Telephone
Junction Lines
B
A
Trans.
Speaking Key
Induction
Coil
Speaking
2 Cells Agg.
Black
Red
Trunk
Ringing
10 Cells
Generator
DR.96

Fig. 13.

trunk circuit, the black keys can be brought into use to obtain attention. Mr. Gavey.

Fig. 13 illustrates the connections on an "A" or "B" section.

4. Communication between different sections in one office to admit of joining one trunk circuit through to another can be effected in several ways. The most simple method of dealing with the problem consists in providing direct junction wires between each section and all the others; and this plan has been adopted where the sections are four or less in number, or where through trunking will, from the nature of the traffic, be infrequent. At large offices, however, the number of junctions necessary for this system would be very considerable; and, as in practice it would be necessary to limit this number, then each junction would have to be multipled along all the sections. To work these would involve the following operations:—

First: Testing for the engaged signal;

Secondly: Ringing up the section wanted;

Thirdly: On receipt of reply, transmitting the demand; these operations in practice involving more or less delay.

To overcome these difficulties, a modification of the divided board arrangement was introduced, which is, briefly, as follows:—

A through trunking or transfer section, sufficient to meet the requirements of 50 trunks, is provided for each ten ordinary sections. From each section three "down" junction wires bearing the number of the section, and lettered A^1, A^2, A^3, are carried to the transfer section, where they terminate in cords and pegs. Similarly, two "up" junctions, terminated on jacks numbered and lettered B^1, B^2, start from the transfer section to the respective switches, where they terminate in jacks. The transfer switch is fitted with a three-position key for each "A" junction—

1st position	...	...	Normal;
2nd position	...	...	Speaking;
3rd position	...	...	Through;

and both these and the jacks are provided with contacts which actuate small grid indicators, which have in practice receive

Mr. Gavey. the somewhat inappropriate name of "visual indicators," through local circuits.

The method of working is, briefly, as follows:—Glasgow requires communication with Cardiff, which at present would be obtained through Leeds. Glasgow calls Leeds, obtaining attention on, say, section **3**, whilst the Cardiff trunk is, say, on section 14. The Leeds operator on section 3, on hearing the requirement, simply pegs Glasgow trunk through a disengaged "A" junction to the transfer switch, and this operation actuates a visual indicator on the junction at the latter point. The operator at the transfer switch then turns the key to "Speaking," and ascertains from Glasgow what is required, whilst the act of turning the key to "Speaking" drops a visual at section 3, which intimates to the operator at that section that the requirement is having attention. The transfer operator, on hearing that Cardiff trunk is wanted, pegs the "A" junction from section 3 into a "B" junction to section 14, thereby dropping a visual at the latter. The operator at this section, in pegging in a cord to reply, drops a visual at the transfer section corresponding to the "B" junction brought into use, which shows that the call is being attended to at the section on which the Cardiff trunks are terminated. The operator in charge of the latter then completes the connection.

The talking is thus reduced to a minimum, being limited to two repetitions of the request for the Cardiff trunk, the automatic signals in all cases intimating to the operator who has pegged a trunk or a junction through that the next individual is attending to the call. None of these visuals are in the line circuit, but they are joined up on local circuits, and they remain depressed as long as the trunks are through. When the conversation is complete, this is indicated at sections 3 and 14 by the automatic signals from Glasgow and Cardiff respectively. The operators at these sections by withdrawing the pegs release the visuals at the transfer. The transfer operator on observing this withdraws the connecting peg and restores the speaking key to "Normal," which also releases the visual of switches 3 and 14.

The connections for direct junctions connecting limited number

of sections in small offices are shown in Fig. 14, whilst Fig. 15 illustrates the transfer board working. Mr. Gavey.

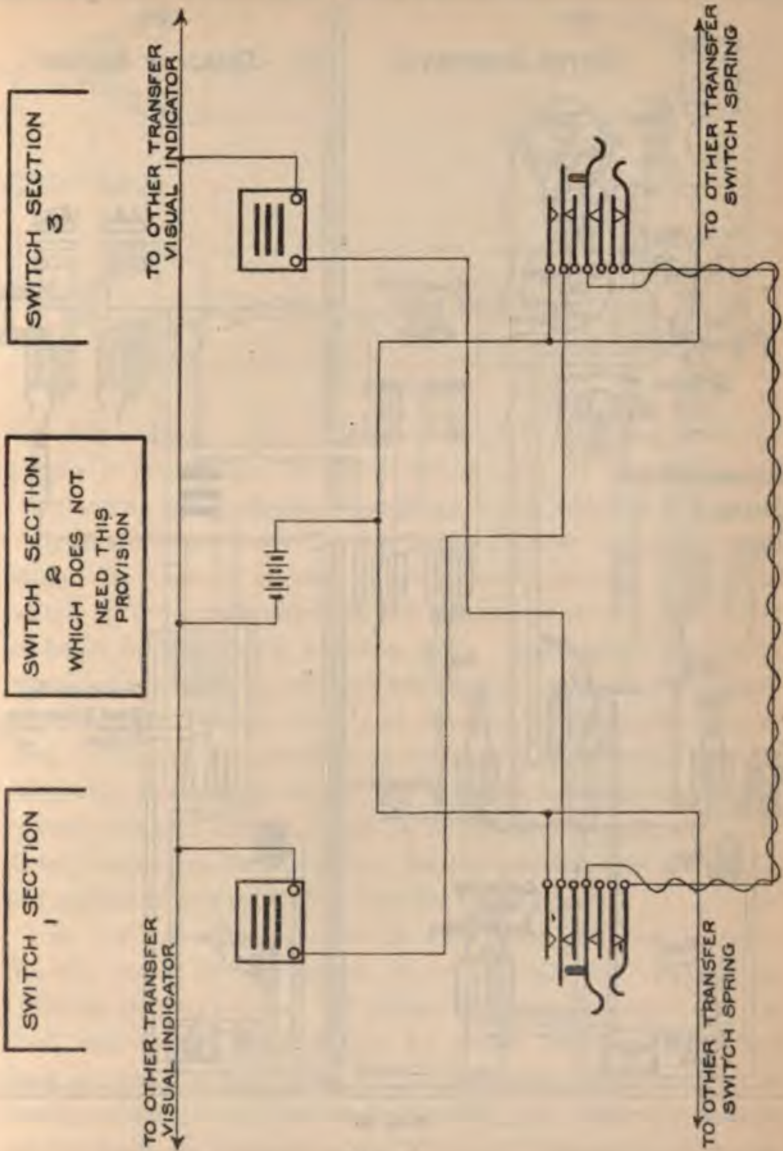

Fig. 14.

5. The general details have been partially illustrated by the

Mr. Gavey preceding figures. Actual switch and transfer sections have been

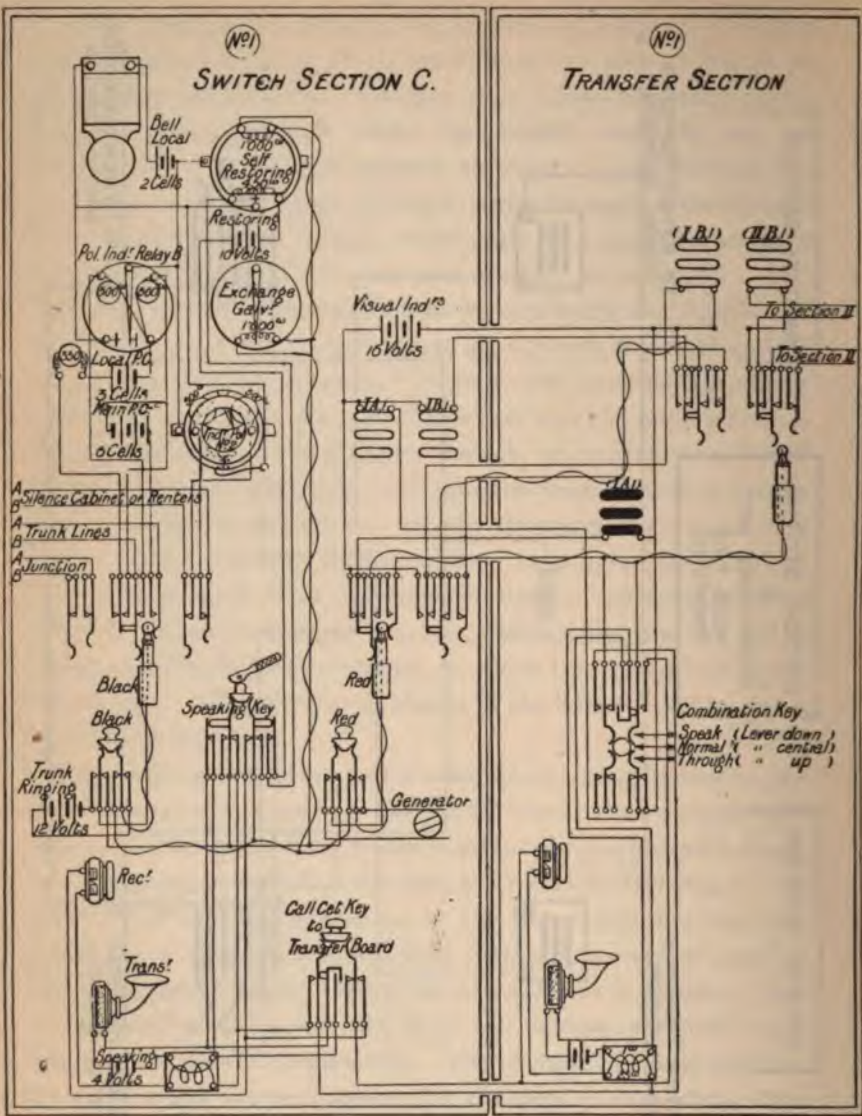

Fig. 15

joined up in this room, and can be inspected at the close of the meeting. They are illustrated in Figs. 17 and 18.

The system of duplex working that has been used by the National Telephone Company for some time has been adopted by Mr. Gavey

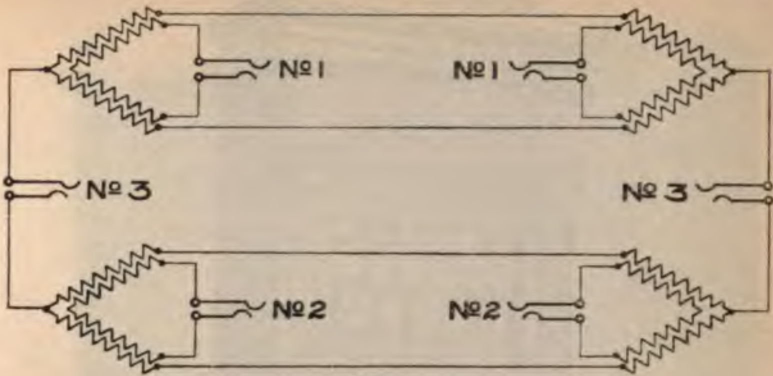

FIG. 16.

the Department. Fig. 16 gives a diagrammatic sketch of the method of joining up. In this it will be observed that differential transformers are used, the secondaries being accurately balanced both for resistance and self-induction before they leave the workshop. No variable resistances are inserted, as any attempt to adjust in order to compensate for variations in the line would probably be a perfectly hopeless task. Under these conditions circuits of moderate length work satisfactorily, no ordinary changes in insulation resistance causing an upset of the duplex working so long as each of the arms is in sufficiently good order to work efficiently as a simple circuit. It is found, however, that if the circuits exceed a certain length it is difficult to maintain satisfactory duplex working; so that, for the present, this method is not applied to any exceeding 50 miles in length.

In the preceding remarks an endeavour has been made to describe succinctly the system of working adopted by the Post Office for its trunk lines. Of course these arrangements are not final, and already modifications are under consideration which have in view the facilitating of the switching operations by the further substitution of automatic signalling for verbal instructions on the junctions connecting the National Company's exchanges with the post offices. The growth of the system itself is progressing by leaps and bounds, and although trunk telephony is

Fig. 17.

but of modern growth, and has in the past served rather as an adjunct to the ordinary methods of telegraphing, the time is Mr. Gavey.

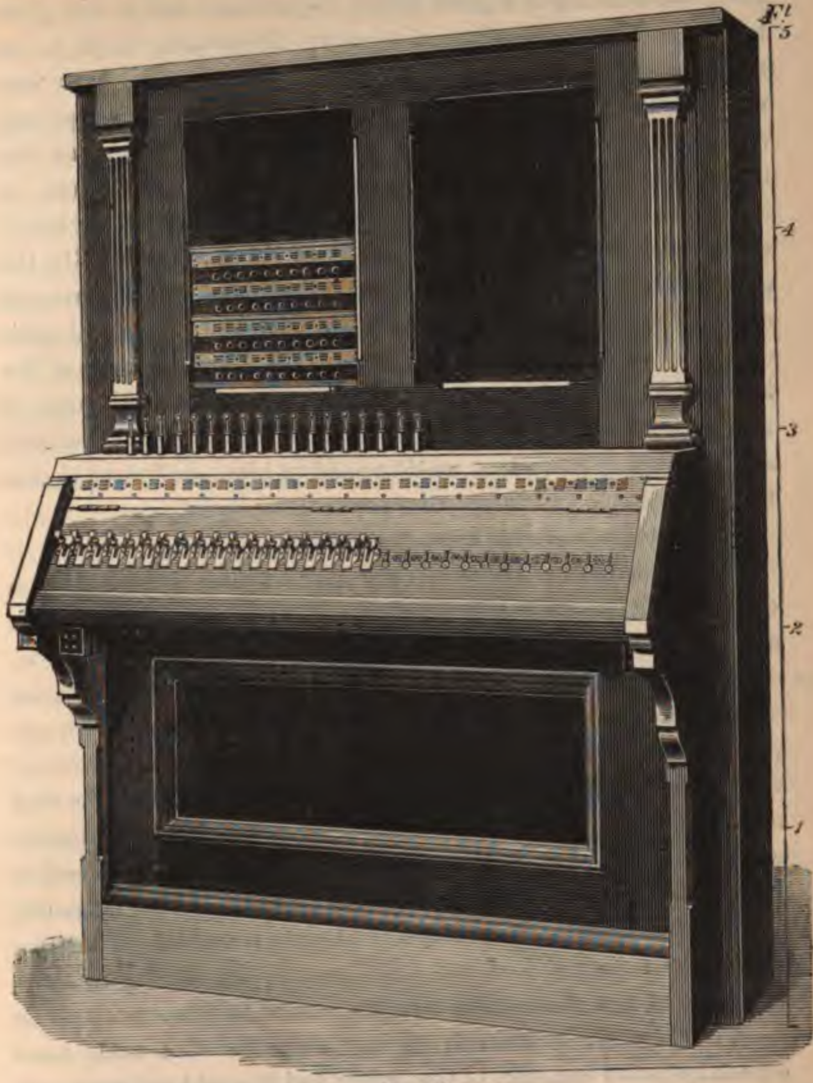

Fig. 18.

rapidly approaching when it will rival the older methods in the extent of the plant, and in the importance, if not in the number, of daily transactions.

The President.

The PRESIDENT: Gentlemen,—We have this evening heard a most interesting and valuable paper. Mr. Gavey has told us of the inner working of a great public Department, and he has given us a great deal of information about the details which it has taken combined brains to develop, because there must have been more than one mind at work upon this system. That is precisely the kind of paper we want. Mr. Gavey has told us a great deal that we could not otherwise get to know; he has given us information which we cannot obtain from other sources. But I think that the import of his paper does not stop there. In the early part of his paper he has thrown upon the subject generally a great deal of light from a purely scientific and theoretical point of view. And so both from the practical point of view of the information he has given us, and from the theoretical point of view of the suggestions he has made to us, I think we all owe him, and I therefore move that we do accord to him, our hearty thanks for his very able and interesting paper this evening.

The motion was unanimously carried.

The PRESIDENT: There is only a short time left to us this evening, but perhaps Mr. Sinclair will open the discussion by allowing us to hear what he has to say on the subject.

Mr. Sinclair

Mr. DANE SINCLAIR: I should open my remarks with a great deal more heart if I found that I could quarrel more with the paper than I can do. I do not know whether the instinct of fighting is as strong in most men as it is in me, but I do wish my friend Mr. Gavey had given me much more reason to quarrel with him. The fact is that the paper, from beginning to end, is such that the only remark I have really to make about it broadly is this—that I wish I had been able to write it myself. There are one or two points that must be specially interesting to those members of the Association who are not immediately telephone men. They are contained, as our President has said, more especially in the first part of the paper; and it would not serve any purpose for me to go over the subject with you further than to say that, so far as my experience goes, I am in exact accord with the words and with the ideas that Mr. Gavey has given you. It is now a good many years since these problems began staring tele-

graph engineers in the face. I remember the days when we listened to induction, and when we used to declare it was heavy rain at the other end of the line. Some people thought that it was a heavy hailstorm. Many other theories were concocted. But what has been done by various leaders in this science has led one and all of those who are immediately connected with it to get at the facts as they absolutely exist; and a more concise or more clear explanation could not, I think, have been given you than Mr. Gavey has given to-night. I had made a note when Mr. Gavey was reading the paper of one point that I was going to criticise, but, as usual, he took the pith out of it in his closing remarks. He there described the use of the call wires between the company's exchanges and the post offices generally. I was going to add what he has now added, viz., that we are beginning to find that improvements can be made in this direction by having more of the automatic signals and less talking. That is a subject which everyone who is immediately connected with this branch thoroughly realises. There is only one other point that I would refer to, and I am glad that Mr. Gavey has referred to it—that is, the duplexing of telephone lines. I think it is not too much for us to say that perhaps in this country we have done more in the actual working of duplex telephony than has been done in any other country. In most other countries they lead us in some points, but I think duplex telephony is one where, from a practical point of view, we have perhaps done most. At any rate, so far as I know, that is the case. Before the transfer of our trunk lines to the Post Office I think the mileage of wire actually working under duplex conditions was very considerable. I forget the actual mileage of wire, but there were something like 60 or 70 duplex circuits, averaging some 30 or 40 miles long, working every day; and I am sure, now that this matter is in the able hands of our friends in the Post Office, that it will be carried out to a greater extent. We can all see the immense importance it has. When you have two wires from London to Liverpool, which are in the first place costly, and when you can with only a little manipulation at the ends, and the introduction of a few coils, jacks, and cords, convert those two

Mr. Sinclair

Mr. Sinclair. long and expensive circuits into three and give your subscribers equally good working, then you have done something which is of very great importance. I hope that some of my other friends will find much more to say. There is really nothing for me to do other than compliment Mr. Gavey on his paper, and the Department on the extreme care with which every detail has been attended to and carried out in practice. I was last week in Sweden and Denmark, seriously examining all their connections of working wires at Stockholm and at Copenhagen; and, while they do much that is very excellent, I think, although it is invidious to make comparisons, that if the gentlemen I met there were here to-night and saw the arrangements that have been provided for the work in this country, they would agree with me that it would be very difficult to improve upon them in any way. I am sure that those gentlemen I have had the pleasure of meeting there would say what I have said, although they have done very excellent work in those countries.

At the next meeting I hope to be able to add a note on the limit of telephonic conversation on underground wires when joined up to trunk lines.

The meeting then adjourned.

The Two Hundred and Ninety-third Ordinary General Meeting of the Institution was held at the Institution of Civil Engineers, 25, Great George Street, Westminster, on Thursday evening, November 26th, 1896—Sir HENRY MANCE, C.I.E., Vice-President, in the Chair.

The minutes of the Ordinary General Meeting held on November 12th, 1896, were read and approved.

Mr. R. W. Weekes, Member, and Mr. F. C. Raphael, Associate, were appointed scrutineers of the ballot.

The CHAIRMAN: We will now continue the discussion on Mr. Gavey's paper; but before commencing I should like to ask Mr. Gavey if he can give us any information as to whether he has found the telephone circuits affected injuriously by the electrical tramways, because any information on that point would, I am sure, be welcomed by electrical engineers who are concerned in the installation of electrical tramways in different parts of the country. Sir Henry Mance.

Mr. J. GAVEY: In response to your inquiry, I can only say that the introductory portion of the paper deals with the theoretical conditions which will ensure immunity from disturbances due to neighbouring circuits, whether these are used for electric tramways, for electric lighting, for telegraphs, or for other purposes. The one method of avoiding trouble consists in the use of metallic loops, and if these are erected in the manner described in the introductory portion of the paper, I think it may be assumed that such telephone circuits will be absolutely free from all trouble due to external conductors. Mr. Gavey.

With regard to single-wire circuits, we cannot, with our present apparatus and methods of working, obtain immunity from disturbance arising from neighbouring conductors conveying variable currents.

Mr. J. E. KINGSBURY: I am bound to say that I am in entire sympathy with Mr. Sinclair's remark at the last meeting that Mr. Kingsbury.

Mr. Kingsbury.

there was nothing to quarrel with in Mr. Gavey's paper. However, I do not know that we ought to regard discussions as being entirely made up of quarrels, and to consider that if we have no fault to find we have no remarks to make. The paper is one on a subject which is certainly capable of a great many remarks; at the same time, it is one which does not lend itself to very much criticism. The reason, I suppose, is obvious. The paper describes the system of working trunk lines adopted by the Government, and I presume we would all expect that the Department would attack that problem in a manner which would lead to satisfactory results. Having taken due care, Mr. Gavey has brought before us a paper which describes the system adopted, and which leaves us no opportunity of adverse criticism With regard to the theoretical principles laid down by Mr. Gavey—and, so far as I am aware, laid down more thoroughly and succinctly than ever before—those theoretical principles applied to practice lead to the laying of the trunk lines on the twist system as described. Mr. Gavey, however, mentions that in some cases the twist is set aside for the cross system. I would simply ask Mr. Gavey to let us know whether in a large number of circuits the cross system is more readily amenable to treatment than the twist system. Another point treated of by Mr. Gavey is the possibility of delay by the trunk work being undertaken by the Government. The argument used by Mr. Gavey is certainly a strong one, and one which I think many had previously overlooked. At the same time, I am inclined to think that Mr. Gavey himself, if he had the opportunity, would see that there must be some advantage in unity of control. Although, as I said, I have no fault to find, I would like to make a suggestion that comes under the head of nomenclature. Throughout the paper there are several references to "pegs." Now, as most of us know them as "plugs," I want to put in a small appeal to Mr. Gavey, and to ask whether he could not, now that he has adopted "jacks," go a little further and adopt "plugs" also. This question of names is not altogether an unimportant one. There are, for example, visual indicators. Mr. Gavey says that the name "visual indi-

"cator" is somewhat inappropriate. As a matter of fact, we have been in the habit of calling them "visual signals," and I think Mr. Gavey does so himself sometimes. An "indication" and a "signal" are practically synonymous terms, but there is a difference in use between the two words, "indicator" being used to indicate a call on a line, and "signal" as a sign that the line is engaged. It is true that in the case of the Post Office system one instrument serves the two purposes. I allude to the local system of service in the Post Office, where a needle is deflected into three positions, and shows three conditions or three states of the line. But the visual signals used, for example, on the switch-boards that we saw here on the last occasion are signals which are independent of the line and show an engaged or disengaged condition of the line according to the position of the signal. The system also referred to as having been inaugurated by Mr. Preece is undoubtedly from the subscriber's point of view a most admirable system. As a subscriber must necessarily take off the telephone from its hook before he can listen, it is a very great advantage to be able to send the signal automatically. That is what is performed by the Post Office system. But one must not overlook the fact that there are different ways of obtaining that result so far as the call goes, and the system adopted by the Post Office has not been largely used; although, as Mr. Preece himself has said, the disadvantages attending that system are only noticed by those who have not used it. That is one of the questions that we must leave open. I only allude to it now in order to say that I think some system of the sort is the system that will survive. Speaking from a subscriber's point of view, the system of taking the telephone from the hook and thereby sending a signal, and hanging it up and thereby sending another signal, is just that simplicity of operation which one may expect to be attained in the future. It exists at present in other systems than the Post Office; and I think I may say that it is being watched with great care, and with some expectation that it is one that will survive. The only other remark I would make is that I think some might consider that the designing of the system, and the preparation of this switch-board and other material, together with the transfer

Mr. Kingsbury.

Mr. Kingsbury. of the trunk lines, as described by Mr. Gavey, is very simple. Mr. Gavey read his paper in about 40 minutes, and it is not easy for many to realise what work is at the back of it. I am sure some persons may be under the impression that nothing is easier than to devise such a system, and arrange a transfer of so many important lines; but it is only those who can get behind these diagrams and know something of the work involved who can form any conception of the arduous nature of the undertaking, and what hard work has been done both by the Department and the Telephone Company. In the case of the Post Office the task has perhaps been more than usually difficult, by reason of having to combine the two systems. The care which has been taken must have been immense to have avoided anything like complications, and I think they are to be congratulated on the success which has been attained, as also Mr. Gavey on the able paper which he has prepared.

Mr. O'Gorman. Mr. M. J. P. O'Gorman: I should like to inquire, in the spirit of a scientific student, what is the telephonic value of the line from instrument to instrument, including the local lines, the switch-board connections, the trunk connections, and the heavy trunk main. The object of this question is to elicit the basis of calculation used for determining the particular values of the conductors employed. Indirectly, we should then see whether the 800-lb. copper used by the Post Office is not in part necessitated by the 20-lb. copper employed by the Telephone Company in local lines. From this we shall discover if a single scientific management of England's telephone system would not be an enormous economy to the country.

Mr. Phillips. Mr. C. J. Phillips: I have nothing to say on this subject except to echo the sentiments of previous speakers. Mr. Gavey has explained everything so clearly in his paper that he has left very little room for discussion. I may mention one point with regard to the boards which we saw here last week. Those boards showed a considerable amount of spare space; there was no necessity for any crowding of the apparatus; consequently the signals used were of rather large size. In many of our exchanges, where we are dealing with large numbers of wires,

every atom of space is of the greatest moment. In these cases, instead of the visual indicators shown on the Post Office boards, we use small lamps, similar to those which are used very largely now throughout America. Each lamp goes into the same space as an ordinary jack; 20 of them can be put on a strip measuring $11\frac{1}{2}$ inches by $\frac{1}{2}$ inch. They are lighted by the closing of a relay which is actuated by the withdrawal of a plug at the distant end of the junction wire. We have them working largely now in London, and we find very great assistance from them. Mr. Phillips.

Mr. A. A. CAMPBELL SWINTON: I should like to make a suggestion which I think arises out of this paper, though it really deals more with the business management of the telephone companies and the Post Office than with technical matters. I subscribe to the National Telephone Company myself, and I sometimes wish to use the trunk lines; but I am met with this difficulty: that when I wish to talk to somebody a long way off—say Newcastle-on-Tyne—unless I send a telegram beforehand to make an appointment with my friend at the other end, I am sometimes put to great expense for no advantage. I remember a little time ago wishing to talk to a gentleman in Manchester—a member of the Council of this Institution—and, though the gentleman was in the neighbourhood of his office, it cost me some 15s. before he came to the telephone and we began our conversation. That is very expensive if you have to do it often. I would ask whether some arrangement could not be made whereby at a small charge—say of 6d., or 1s. in the case of longer lines—the Post Office and the Telephone Company jointly could not take upon themselves the making of telephonic appointments; so that you might be able to go to your telephone and say that you wish to speak to Mr. So-and-So in some other town, and that you want to be rung up as soon as he is ready. The message need not necessarily go from town to town by telephone; it might go by telegraph, which would possibly be cheaper. If some arrangement of that kind could be made, I think it would lead to trunk lines being used much more largely than they are at present; because you would only pay a small amount in order to ensure the presence of the person at the other end to whom you wished to speak, and only Mr. Swinton.

Mr. Swinton. after having got him there would the ordinary tariff commence. At present you have to keep paying considerable sums of money every three minutes while you are merely waiting for the other person to come to the telephone, and in the event of your friend being out or engaged you may have all your expense for nothing.

General Webber. General WEBBER [*communicated*]: The interest in Mr. Gavey's paper lies chiefly in the description of the machinery, which includes physical, mechanical, and electrical means used to provide intercommunication between telephone exchanges. As I listened to his description, and with deep interest as a telegraph engineer realised much that it means now and in the future, I could well conceive that possibly the Postal telegraph authorities might well devoutly wish that such a thing as a telephone had never been invented. When one compares the great differences which exist between the two processes as a means of communication, it would not be surprising if such were the case. With telegraphy, as a means of receiving a written message, and of handing a true copy of it to an addressee within a reasonable time, the telegraph in the United Kingdom has, I believe, achieved the maximum of efficiency. It may fairly be said that the authorities have no need to take the public into their confidence by describing the details of the process as to *how* they render the service. So long as the sender of a telegram writes distinctly on the prescribed form, pays the charge at the tariff rate, attaches the stamps, and hands the form to the telegraph clerk, he is morally certain that within half an hour, with time for delivery at the addressee's residence added, a true copy will be delivered, under cover, which no one is entitled to open except his correspondent. How widely different is the nature and extent of the service to the public which the Post Office is now beginning to develop, is only in a minute degree divulged to you by Mr. Gavey's most interesting description, and can hardly be realised even by the majority of his audience.

It has been especially interesting and, if Mr. Sinclair will not mind my saying so, amusing, to find that the Telephone Company agrees in the wisdom of the alterations in their trunk line switch-room arrangements carried out by the Post Office. Those who

ought to have been the best pioneers of the use of trunk lines, are prescribed for by those whose practical experience in trunk line telephony had been *nil*. Mr. Sinclair's failure last evening to defend his older system does not necessarily mean that he agrees with all the automatic arrangements now being brought into use. Mr. Gavey's admission that alterations and improvements may be necessary, is hopeful that the Post Office may be trembling a little at the gigantic size of the task before it. How far that task means the gradual substitution of the telephone for the telegraph in the United Kingdom, is a question too serious for anyone to "sit on the rail" about, much less a great public Department. General Webber.

The reading of this paper of Mr. Gavey's before the Institution helps to confirm what I have already contended for here and elsewhere—namely, that the provision and working of means by which any two persons can converse at a distance is chiefly an engineering operation. In the telegraph service of this country it has always been contended—not by telegraph engineers—that the process of communicating the contents of a written document from one person to another was a commercial operation, having a strong family resemblance to the letter post, and the engineers have only been responsible for the mechanical and electrical part of those means. In telephony, the user—*i.e.*, the public—undertakes the physical part of the message work, and all the rest is, or should be, under one control—at least, so I have always contended—whether the actual labour is male or female. I don't know whether the Post Office has adopted that view. If they have not, I think they have added an unnecessary factor to their troubles ahead. If it is said that, because the telegraph instrument clerks in the Post Office have been always under different control and direction to the engineers who erect and maintain the lines and instruments, therefore the switch-room ladies should be similarly separated in their allegiance, because they operate the jacks of a switch-board, I beg to remark that it would be like placing the boy who oils the machinery under the commercial clerk of a large engineering factory. The fact that an engineer—and a distinguished one—of the Post Office has given us the description of this interesting and complicated operation, I hope

General Webber.

tends to show that my contention is correct. If so, it may alter a very decided line of policy which the Post Office inaugurated when it took over the telegraphs in 1870, and one which I am sure will have a marked effect on the future of telephony.

The operation of transmitting a telegraphic message from the counter of one country telegraphic office to an individual at his residence in another part of the country has never been described in detail in our annals, although I have described it minutely elsewhere. It is enough to mention that if the message has to be *transmitted* at two intermediate offices, which is very usually the case, it has to be handled by perhaps eight persons, and at least four copies of the original one have to be made. Mr. Gavey has described how far the process of putting two persons in communication by telephone means something that is very different in its composition. That it must be directed and controlled in a different manner to that heretofore followed by telegraphy in this country, should success on a large scale be intended, is my contention, which means a radical change in the organisation of the *personnel*, in view of certain success; and absolute success is the only result the public will be satisfied with. This policy seems to me to be imperative. Telephony is, from beginning to end, an engineering operation. I have not the slightest hesitation, with my own personal intimate knowledge of the history of its career, in stating that to the great absence of recognition of this fact has been due its shortcomings in this country. To this preponderance of a so-called commercial policy is due—

The irrevocable mistakes made when the first rival companies, Bell and Edison, were amalgamated.

The decision, against advice given in 1880, to provide earth return in all systems not purely local.

The hap-hazard extension of the metropolitan systems, by which London, for its size, is the worst telephoned city in the world, and never likely to be better in our lifetime.

And so on; it would take pages to give a list of the procedure under which what may be called the engineering management of the telephone has been subordinated to the commercial.

General Webber.

The public has never yet obtained any declaration from the Government of what it contemplates to be the future of telephony in this country The late Postmaster-General, as chairman of the House of Commons committee which sat in April, 1895, certainly gave the impression that he regarded the further use of the telephone as restricted to a small minority. The reasons for this were suggested in papers read by Mr. A. R. Bennett and me at the British Association meeting at Ipswich in 1895. I have lately addressed the *Electrical Review* on the subject in terms which I hoped would have encouraged some official announcement. My object has always been to urge on the Post Office the policy of encouraging private or local enterprise in district telephones, and that they should place no restrictions whatever on efforts in that direction, but that they should claim and take the supervision of all those exchange circuits which are destined to be joined on to their trunk lines, controlling their construction and maintenance so as to ensure uniformity and a standard of efficiency. Although they have gone far in committing themselves to a policy by which every present subscriber to the Telephone Company's system has a right to be "put through" on the trunk lines, they have not gone too far. It would be well worth paying a large sum to the National Company to secure the classification of subscribers under two heads, namely:—

(*a*) Those wishing to be able to speak inside a given district, or, in other words, those who *don't* want to use the trunk lines;

(*b*) Those subscribers who *do* want to use them;

and that *they* (the Post Office) shall have the right to specify the lines and instruments used, or to be used, under class (*b*), and to inspect and supervise the same, so as to ensure a standard of construction and maintenance equal to that of the trunk lines, sufficient to provide a good service. Unless this classification is secured, I can see nothing for the telephone in this country but a prohibitive monopoly having as a chief result the restriction of its use through a low efficiency and by high tariffs. Assuming that the call offices in the county of Suffolk alone could number in the future that described by me in the paper referred to—namely, 350,

General Webber. or about one per 1,000 of the population—and that one-third of these were certified as available for trunk line speaking, the question—every hour of greater moment—is, whether the Post Office is preparing to provide trunk lines so that even a total of 8,230 call offices, besides those in the great cities, can intercommunicate. This figure of 8,230 represents one call office per 3,000 of population in 25,850,000, being the population of Great Britain and Ireland after deducting 11,900,000, which represents the population of London and 35 large towns. In these town areas the call offices might be one per 5,000 of population, which would require 2,380 in addition, or a total of 8,230 + 2,380 = 10,610.

It is difficult, perhaps, to estimate the probable number of private connections which will eventually—say within the next ten years—elect to pay for a trunk line telephone. The natural answer is, that it all depends on the cost and efficiency of the service; but I would urge that it also depends on whether facilities are given for the widest extension of the use of local telephones, by which this means of intercommunicating may enter more and more into the daily life of the people; which must be the case, I submit, as education and intelligence increase.

Returning to the examples and figures previously given, I find I have designed 30 exchanges for the county of Suffolk, or one per 11,792 of population. All of these exchanges would be in communication with the trunk line system, and at that rate there would be about 2,192 of them. To estimate the number of subscribers connected to these who would require trunk line intercourse would be largely guess work. Perhaps an average of 50 on each, *i.e.*, a total of 110,000. This may be considered a low estimate, but I think not when a trunk line call office is within reach. With the 11,900,000 population of London and 35 large towns the estimate must be differently dealt with. Mr. Bennett puts the subscribers to the present telephone exchanges in the United Kingdom at one for 636 of population, but these are almost all included in the large town areas. In 1894 there were 60,000 subscribers to the exchanges of the United Kingdom. The nature of the business to which telephony is largely confined in this country, owing to the cost of the service, permits an

estimate that quite double that number will elect for a trunk line telephone. General Webber.

My estimate, therefore, points to the following as a total to be borne in mind when considering the subject, viz. :—

Call offices	10,610
Subscribers in London and the 35 large towns who will require trunk line communication ...	120,000
Subscribers in the country areas who will also require trunk line communication within the next few years	110,000
	240,610

Now this, although a large figure, is not a very unmanageable one; but the meeting will understand that its limitation is entirely governed by the adoption of the policy for the future which I have tried to make intelligible. To what the local telephone service may increase it is difficult to foresee, if free trade in its extension is allowed. Including urban and rural, in the Duchy of Luxemburg there is an exchange for every 3,577 of the population; in Norway one for 7,812; in the United Kingdom one for 65,537. I think it best to carry my remarks no further in this interesting direction, momentous for the future of business and social intercourse in this country, although there is much to be said.

Mr. DANE SINCLAIR: If General Webber were here, I should have made some remarks, which under the circumstances I must refrain from making, with reference to the first part of his communication. The General says that I have acquiesced in the introduction by the Government of automatic signals. I am not aware of ever having taken any stand on any particular system. So far as I know, we have all been on the look-out for the best. But we have had to deal with apparatus which already existed, and which it was impossible to alter at short notice. It is thus only lately that we have been able to introduce visual signals, now working on several hundred wires. This, of course, could hardly be known to the writer of the notes, and we will not blame him seriously for not knowing something that was not within his usual Mr. Sinclair.

Mr. Sinclair. domain. Automatic visual signals afford many facilities that are not given by the ordinary ringing system. On the other hand, of course, the ringing system does offer in connection with trunk line business some facilities unobtainable with the former; and, although I have not discussed the question very thoroughly with my friends in the Post Office, I should not be astonished to hear some of them say that the combination of the two, with good and proper management, may lead to the best result of all. At any rate, I am at one with the Post Office in saying that the visual system is best for trunk line purposes, where the earning power is large, as compared with that of the short local lines, for which I suspect, from the General's remarks, only a small rent is to be paid. But though it might be reasonable where there is a lot of money earned, it might not be reasonable for a more ordinary concern. If the permanent-current system is carried out universally on trunk lines, and on the local lines at each end, certain difficulties arise which would not exist if it were employed on the trunk lines only. I think that Mr. Gavey and other gentlemen connected with the Post Office will be as ready to admit this as we are. General Webber gives a good many figures and reasons for comparing the relative cost and efficiency of the telephone system of this country with those of other countries. I am sure you will agree with me that as an Institution of Electrical Engineers we are hardly in a position to go into the *pros* and *cons* of policy, or of what the charges ought to be. These matters are really in other hands. Not that I should be afraid to take the matter up with anyone who was honestly intending to deal with it, and who would look at the matter in an unbiased way. This, however, is hardly the place, in my opinion, for these discussions. We are here as electrical engineers; and if you can find fault with Mr. Gavey's electrical arrangements, or with mine, we shall be only too glad to take the lesson to heart from any member of this Institution.

Professor Ayrton. Professor W. E. AYRTON: I should like to commence by congratulating Mr. Gavey on having given us a most interesting paper. It is interesting from a variety of reasons. Many of us have heard a great deal about the trunk telephone lines that have

been constructed, and are being constructed, in this country, and we were all most anxious to know something about the details. It is also, I think, very important that we should remember that, although problems involving, say, hysteresis and trolley wires for tram lines are no doubt entrancing, there is something else which is important to electrical engineers, and that is telegraphic and telephonic considerations. In the old days we busied ourselves entirely, or almost entirely, with accounts of the difficulties and investigations connected with the telegraph. In recent times other interests, of course, have come to the front. But the telegraph is not only not less important than it was 25 years ago, but it is even more important; and, so far from having fewer papers per year on that subject, we ought to have more than ever. Telephones, again, did not exist at all 25 years ago, and now they are nearly universal. Hence what ought to surprise us should be that this Institution received any papers at all which do not involve telegraphic or telephonic considerations, instead of the fact that such papers are somewhat rare at our meetings. I, therefore, heartily congratulate Mr. Gavey on having given us this interesting account of the trunk line system of this country. Professor Ayrton.

The point of his paper on which I should like to say a few words is the introductory part. Perhaps Mr. Gavey will kindly give me a little more information on one or two points. Some of you know that I have been interested for a long time on this question of electrostatic and electro-magnetic disturbance. I have turned up a volume of the Journal of the old Society—the Society of Telegraphic Engineers—viz., that for 1880, and I find there several papers on the subject of disturbances on telegraph lines. They seem to have started by a paper by Mr. Wilson, of Chicago, who attempted to compensate for the effects of electrostatic induction. I also seem to have tackled the thing myself; and then Mr. Heaviside took it up in a more complete way. Mr. Gavey gives the resistances and inductive capacity of various over-ground wires used in practice. He speaks of the capacity to earth, and of the capacity wire to wire. I am not quite clear whether there were eight wires, as in his figure, or how many there were on the arms during his tests; and I should like to know whether, in

Professor Ayrton.

measuring this capacity, all the other wires joined together. My reason for asking is that, according to Mr. Gavey's results, the capacity wire to wire is 0·6 of that of the wire to earth. I found, however, and somewhat later—in 1880—Mr. Oliver Heaviside also arrived, from purely theoretical calculations, at a result which agreed with mine, viz., that the capacity from one wire to another wire on a post, in certain definite cases that are given, should be greater than the capacity of that wire to the earth. In Mr. Heaviside's case there were four wires, 1 and 2 being 18 inches apart horizontally, and also 3 and 4, while the height of the one pair, 1 and 2, above the other pair, 3 and 4, was 1 foot; and he came to the conclusion that the capacity of one wire to another wire was greater than the capacity of a wire to the earth. Treating it in a somewhat different way, I seem to have come to the same conclusion. I should be glad, therefore, if Mr. Gavey would give us the details of the circuits to which he refers.

At another part of the paper it is stated that "normally the "currents due to electro-magnetic induction would be more con-"siderable than those arising from electrostatic induction in a "single-wire circuit with an earth return." He adds that experiments made between Newport, Cardiff, Swansea, and Haverfordwest, between ordinary parallel wires, showed that the electro-magnetic disturbance was much greater than the electro-static—about 30 times as great. I should like to know the length of the circuit on which these experiments were actually made. There is an interesting result in connection with electrostatic and electro-magnetic disturbance which was arrived at through these early calculations to which I have referred, and that was, that if you increased the length of the line the electro-static disturbance increased more rapidly than the electro-magnetic. I see, from a calculation of mine given in some detail in the Society's Journal for 1880, that, whereas for a short line electro-magnetic disturbance might be the more important, as you went on increasing the length of the line the electrostatic disturbance ought to gradually preponderate. Without entering into all *the formulæ* one can see in a general way why that conclusion

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must be true. Supposing you consider two wires of a certain length, and send through one of them, which we may call A, a definite current, and then stop it. There will be a certain electro-motive force per yard or per mile in the secondary wire, B, induced by electro-magnetic action. If you double the length of the two parallel conductors, A and B, you will double the length over which there can be the electro-magnetic induction; but you will, of course, double the resistance of the secondary circuit. I leave out of consideration for the moment the resistance of the receiving instruments. If, then, there were simply wires with no receiving instruments, you would not produce very much difference in the electro-magnetic induction by lengthening the parallel wires, since with a constant value of the current in the primary wire A you would, on stopping it, increase the induced electro-motive force in the secondary wire B in proportion, roughly, to the resistance of this secondary wire. This, of course, would not be absolutely true if you took into account the receiving instruments, because their resistance would remain fairly constant whether the line were 100 or 200 miles long. Next let us consider the question of electrostatic disturbance. If you desire to keep the current in the primary wire constant, whether the line be 100 or 200 miles long, then not only have you a much longer secondary wire—which means a condenser with larger plates and, therefore, more area for electrostatic induction to take place in—but the average electro-motive force must be much greater. If the wire be twice as long, you must, of course, have twice the electro-motive force to send the same current through it; therefore the average potential along your primary wire would be doubled by doubling the length if the current in the primary wire is to be kept constant, and the resistance of the receiving instrument be neglected. Hence we see in a rough way that the electrostatic disturbance will increase with the length of the line. In the case, then, of electro-magnetic disturbance, you do not sensibly increase the disturbance by increasing the length of the lines, if you disregard the resistance of the receiving instruments; whereas with electrostatic disturbance you distinctly increase the effect.

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It would, therefore, be interesting to know the lengths of the actual wires in which the electro-magnetic disturbance was—according to the experiments of Mr. Gavey—30 times as great as the electrostatic.

I now come to another point which everybody connected with telegraphy knows as one of vital importance in connection with the speed of signalling. It is one that has troubled us all for a very long time when we have attempted to tackle it mathematically: I refer to the effect of introducing leaks. From an early paper of Mr. Heaviside's, an abstract of which appears in our Journal—a paper of 1879, published in the *Philosophical Magazine*—I find that he tackled the problem of finding the effect of faults on the speed of working of cables. It is not very difficult to deal with the complete investigation of the action of capacity, resistance, and self-induction. That has been done by Mr. Heaviside, by Lord Kelvin, and this investigation is given in detail in a book by Professor Gray and Professor Matthews on Bessel functions. But when you introduce faults in a line—earth leakages—the problem becomes more complicated. At the same time we know, looking at it roughly, without going into minute mathematical detail, that the application of earth faults must increase the speed of signalling. I should like, therefore, to know from Mr. Sinclair, or from anyone who has such magnificent opportunities as he has for making experiments, whether he can give us any actual details as to the improvements that have been effected on the use of telephone lines by making them very imperfect, as it might be imagined at first sight—that is, by distributing earth leakages along them.

I desire to end, as I began, by warmly congratulating the Institution on having had brought before it a paper which, although not dealing with accumulators, dynamos, nor electric traction, is, nevertheless, full of interest.

Mr. Preece.

Mr. W. H. PREECE: The paper itself exhausts nearly everything that I could say on the subject. It is the result of a promise that I made to the Institution last year. I then brought the subject of the trunk line telephone system before the Society, *and I said* that the details of the system should be brought

before you by Mr. Gavey. I venture to think that not only has Mr. Preece this promise been fulfilled, but that it has been fulfilled in a way of which I may be proud. I do not think that the magnitude of this transfer has been sufficiently appreciated. Everybody thought it an extraordinary big thing when the telegraphic service of this country was transferred to the Government. An immense fuss was made about it at the time; but the transfer which has taken place during the last 12 months so quietly and so successfully has been of a character quite as gigantic as that which took place in 1870. It has gone off well; and the reason that it has gone off so well has been that the officers of the Telephone Company and of the Post Office have worked hand and glove together. The question before the Institution is not whether the service is well done or badly done; the question is, Is it properly done? Has it been done in accordance with accepted doctrines, or is it in accordance with the practice that has been brought before this Institution? If it has not been, it ought to be. It is impossible that any officials on the face of the earth could have devoted more consideration, more industry, and more time to master the intricacies of the telephone question than we have in the Post Office. I have myself been to the United States twice; I have been to Norway, Sweden, Germany, France, and every place where there is anything to be learned. The result has been that we have endeavoured to make the system as between the trunk service of the Post Office and the local service of the Telephone Company as perfect as it can be made. With regard to one point raised by Professor Ayrton—the influence of leaks in working—there is no doubt whatever that in working telegraphs the existence of leaks does expedite the rate of working. There is only one occasion where it does not do so—that is, when the leaks are to earth through absolute faults in a cable; and that probably arises from the fact that at the point where the current escapes to the water, currents of polarisation are set up by electrolysis. We have found this to be the case even with overhead lines insulated with ordinary porcelain insulators. If it were true that leaks expedited the rate of working the telegraphs, we should work much more quickly in

Mr. Preece. wet weather than we do in dry weather. It is not quite the fact, but it is nearly the fact, because in certain cases in dry weather the effect of electrostatic capacity is much increased; but in wet weather there is not the least doubt that this electrolytic action produces a kind of dulling effect on the currents. It flattens the waves. Practically we do not gain speed. When we put in inductive leaks, we do not obtain an improved rate of working; when we put in non-inductive leaks, we do. With regard to the metallic circuit of a telephone, I am sorry to say that up to the present moment we have not made any direct experiments in this direction. Non-inductive resistance between the two arms of a metallic loop might improve the rate of working. I hope either this session or next session to be in a position to bring before this Institution, not only the question of the effect of leakages, but the far more important question, and one that I think will interest the Institution very much—the question of working telephones through submarine cables.

Mr. Gavey. Mr. J. GAVEY, in reply: The points on which I have to reply are not very numerous, as the paper is, perhaps, not of a highly controversial character. Mr. Kingsbury asks what is the longest section of rectilinear wires we have crossed at intervals in order to get rid of induction, and to what extent this system is considered a satisfactory one. Practically speaking, I may say that we have taken half a dozen parallel circuits 30 or 40 miles long, and we have got rid of overhearing by means of crosses of the nature described in the paper; but I should not like to say that we could deal with 40 miles of line carrying 30 or 40 such wires in a satisfactory manner, as ultimately the crosses necessary might become very numerous. We have, however, dealt with 12 or 14 miles of line carrying about 40 wires, with good results. Unquestionably the system of revolving wires is by far the best way of avoiding induction.

The question of the unity of control of the trunk and local systems has been raised. This is a matter of public policy in which I am not at present prepared to follow the speaker. There is another small point—that of nomenclature. My friend *Mr. Kingsbury* suggested that we should use the term "plugs"

instead of "pegs." So long as we are not asked to put a square peg into a round hole I do not care whether we call them "plugs" or "pegs." As to the use of the word "visuals," I considered it inappropriate, because in the natural course of things almost every signalling apparatus that is used in a switch-room (I will not say generally, because the bell is used in the subscriber's office) must necessarily have a visual signal; and whether that signal be indicated by a movement of a needle, the light of a lamp, or the movement of a grid, such as we use on our transfer boards, they are all visuals; it therefore struck me that the use of the term was indefinite. Mr. Gavey.

Mr. O'Gorman has raised a question as to the gauge of copper wires used by the Department, and he has stated that very much heavier wire has been introduced, generally speaking, than that found necessary by the Telephone Company. I think his statement requires a little qualification. I explained in the course of the paper that what we may term the backbone system of the country consisted of very heavy wire, and I gave the reason for the use of that large gauge; but I may say at once that it was not for a moment contemplated making use of this very heavy wire for every telephonic extension throughout the country. The gauge of the wire in use depends on the length of the circuit and the purpose to which it has to be put. Thus we may say that, generally speaking, the minimum gauge adopted by the Department is 150 lbs. per mile—not necessarily because that is the smallest wire that we could use electrically. This limit is fixed solely by physical causes. We know that in certain parts of the country we are subject to combined gales and sleety snowstorms, and our experience has taught us that if we use a smaller gauge than 150 lbs. we expose our lines to the risk of very serious interruptions. A conductor of 50 lbs. gauge would work satisfactorily over a considerable distance, but considerations of safety on one side and economy on the other has led to fixing the limit at 150 lbs. There is another reason why we should not reduce the gauge of wire below a certain limit, and perhaps that reason did not apply to the National Telephone Company when first it erected its trunk lines. The genesis of the system must be borne

Mr. Gavey. in mind. Its growth was gradual. It commenced by the linking together of a few neighbouring towns comparatively short distances apart; and of course the various companies which established these relatively short trunks very naturally thought that the smaller the gauge, and therefore the cheaper the manner in which the communication could be effected, the better it would be for all concerned—the larger the profit to the company, and the cheaper the rate to the public. But now that the system has expanded into a national system, we must bear in mind that any subscriber, or any number of the public in any one town, does not only want to speak to the neighbouring town, but he may wish to speak to a subscriber 300 or 400 miles off, and therefore it may be necessary to link even a short wire a few miles in length to another 300 or 400 miles long. That is another reason why we should not adopt the very small gauges with which the original companies started.

Mr. Phillips has made some reference to the size of the boards or sections used by the Department, and he has pointed out that for a local service something very much smaller and more compact is necessary. Of course I quite agree with him on this point, but in designing the trunk sections there was one limiting factor, namely, the provision of space for one operator to control five trunk lines, and that was defined by the average size of the operator. That, of course, provided more space than is possible in a local system, where an operator controls 50 or 60 subscribers' lines, therefore there was no object in making the apparatus particularly small or particularly compact; it was really desirable to make it very visible and very easily handled. Mr. Phillips refers to the use of lamps for signalling purposes. Lamps are very pretty and taking. I must confess I was very much struck with their appearance when I saw them, but I could not help reflecting that they might be very costly in work, and they would certainly be subject to interruption which might not be readily detected—in other words, if the lamp filament breaks the signal ceases, and some little time must elapse before the existence of the fault is discovered. Personally, I have rather a predilection—naturally enough—for the form that has been adopted by the Department, and which I have *ventured to* call the "grid indicator."

Mr. Campbell Swinton has suggested that if the Department were to make arrangements of such a character as to admit of telephonic appointments, there would be a certain advantage to the public. True; but at what cost to the revenue? I am afraid that it would involve the keeping of a certain number of trunk lines always more or less idle in order to admit of these appointments being kept. It must be borne in mind that during the busy periods of the day there is a constant flow of telephonic calls. As I pointed out in the paper, these calls must all be dealt with in the order of priority of application, and we must absolutely, as a Government Department, observe the principle of code turn. It is impossible to maintain trunk lines partially idle in order that members and the general public may make telephonic appointments, except at a cost which would be absolutely prohibitive. Of course it may be said that this is no satisfaction to the member of the public who has to wait for some length of time in order that his turn may come. With reference to that I should like to say one word. The Department has acquired the trunk system of the country, and it is just starting the actual working. It has created a backbone system uniting all the detached sections into one continuous whole. It is busily at work extending that system, and no doubt it will not stay its hand until the telephonic system throughout the country is as complete in itself as the telegraphic system is. Until that state of things is reached I am afraid that occasionally members of the public may have to wait for a longer period than they think desirable. But we are, as it were, in a state of transition, and it is hoped that it will not be very long before these periods of waiting will be reduced to a minimum, and that all legitimate causes of complaint will be absolutely removed. Mr. Gavey.

Major-General Webber has made a number of remarks, most of refer to which local exchange working, into which, as they scarcely refer to the subject of the paper, I think I need not follow him; there are one or two points, however, to which perhaps I may reply. The question of the use of telephones for commercial purposes is one that has been raised not only by him, but by certain gentlemen in the Press. It may not be generally known that in certain parts

Mr. Gavey. of the country in which the neighbouring towns have for some time been connected by trunk lines, the commercial business between them is now practically effected by telephone. It may surprise some members of the Institution to hear that many of our large towns at the present moment are averaging from 1,000 to 3,000 conversations per diem, most of them being unquestionably commercial conversations. This, it should not be forgotten, is equivalent to double the number of telegrams at least. One other point referred to was the control, or want of control, of the engineering staff of the Department over the operating staff. The question of dividing a service into partially independent branches is very largely a matter of opinion, and still more largely a question of the size or the importance of the institution under review. It is easy to imagine an undertaking in which one individual is the engineer, manager, clerk, messenger, and everything else combined; or, on the other hand, we may take as an example the division of the staff on the great railways of this country. I think, on the whole, nobody questions the effective management of our railway system, and yet the engineer of the railway claims no control over the booking clerk, and I do not think that the system works any the less well in consequence; nor do I think we can say that the Post Office organisation of the telephone branch will be unsatisfactory because the engineer-in-chief does not control the operators. One point in connection with the suggested establishment of cheap local systems: I must confess that I should see with great regret the formation of exchanges in which there were two classes of subscribers—one provided with apparatus on which trunk line conversations could be held, and the other with an apparatus only adapted to local purposes. It would no doubt serve the wants of a little area, where intercommunication would be possible between all the subscribers; but people in distant towns, on calling up the subscribers with the imperfect apparatus, would be unable to hold satisfactory communication, and general disappointment and disgust would be the result. Again, the difference in the value of a good telephonic set and an imperfect one is so trifling that it would never pay any company or individual to use

the cheaper form, in order to economise slightly in the capital account. The cost of maintenance would be the same; or, if there were any difference, it would be greater with the less perfect apparatus. Mr. Gavey.

I now come to the observations of Professor Ayrton. First, I may say that the factor of 0·6 which has been used to reduce the capacity of the wire to earth to that of a wire to wire is solely the result of experiments, and when those experiments were made they were carried out on two conductors, whilst the others were insulated at both ends. As a reason for adopting that course, I may say that the experiments were made as part of a series of telephonic investigations; and as all trunk telephone circuits are loops, and therefore not connected to earth, there appears to be no reason to doubt the accuracy of the results under the conditions given. With reference to the statement on page 630, the observations practically were made on parallel wires between Cardiff and Swansea. The currents were actually put on at Newport, and they traversed the line to Haverfordwest, or *vice versâ*—the object of that arrangement being to prevent transmission through the necessarily more or less imperfect earth; because the joint with the earth is always imperfect, and if any endeavour had been made to send the currents on one wire from Cardiff to Swansea, and to make observations on the other, I need scarcely say that no results of any value could have been obtained. The distance from Newport to Cardiff is about 12 miles, from Cardiff to Swansea about 40 miles, and from Swansea to Haverfordwest about 60 miles. With reference to the other point Professor Ayrton has raised, I quite admit that I committed a little slip in one respect; that is to say, I did not make my meaning quite clear. If we consider the electromagnetic effect from wire to wire alone, the result, when measured in amperes, will be to a great extent independent of the length of the neighbouring wires, for the simple reason given by Professor Ayrton—that the resistance of the wires increases as the E.M.F. increases. But in making these experiments I was rather concerned with the telegraphic, or telephonic, effect, and I was observing the results on a reflecting galvanometer of about 3,000

Mr. Gavey. ohms resistance, and naturally in that particular case the increased resistance of the line was absolutely insignificant; whereas, by doubling the length of the line, the E.M.F., and, consequently, the observed current, were doubled. Without a knowledge of all the data the observations may appear misleading; but, looked at from the practical telegraphic point of view, they represent roughly the effects observed when the apparatus is in circuit at both ends.

Sir Henry Mance. The CHAIRMAN: Gentlemen,—I am sure you will agree with me that we have had a most instructive paper, a very interesting discussion, and an able reply. To an old telegraph official like myself a paper of this kind is especially interesting; indeed, I am inclined to think that only a telegraph man can thoroughly appreciate the skill, trouble, and ingenuity displayed in arranging for the control of the vast number of telephonic circuits connected with the principal telephone exchanges in this country. I think we are agreed that the chief drawback to the use of the telephone is the difficulty we sometimes experience in establishing communication with our friends, especially from the provinces. As I understood Mr. Swinton, he suggested (and I think the suggestion a good one) that we might have some arrangement by which we could use the ordinary telegraph circuits for the purpose of warning distant correspondents. This would lead to great economy of time on the trunk telephone lines. The advantage of using leaks in a circuit has been referred to. I may say so far back as 1864 it was a common practice in the Persian Gulf to use leaks in connection with the cables. We found, not only that the signals were better, but that the speed was increased as much as 10 or 15 per cent., when working through sections of 500 miles, with an artificial leak in the centre. Mr. Preece is quite correct in drawing attention to the fact that faults in the cable might not give quite such satisfactory results; this undoubtedly would be the case when using the recorder or mirror. Every escape of gas from the fault would be noticeable with these instruments, and marked by violent deflections. I am sure it is the desire of the meeting to accord Mr. Gavey a hearty vote of thanks for the interesting paper he has given us.

The CHAIRMAN announced, as the result of the ballot, that the following candidates were elected:—

Associates:

George Adams.	William Harling.
Thomas W. Allan.	Herbert T. Marks.
Robert W. H. M. Bland.	William Edward Moore.
Harold Vincent Bowen.	Charles Steers Peel.
Ivon Braby.	George Stobie.
Arthur F. Evans.	Andrew Sweet.
Thomas Bennett Groves.	Albert Edward Williamson.
Herbert Hampton Hall.	James Cowan Woodburn.

George Herbert Wyatt.

Students:

Alick Jas. Newport Kenneth.	Martin Amyas Shepstone.

Frank King Westbrook.

The meeting then adjourned.

The Twenty-fifth Annual General Meeting of the Institution was held at the Institution of Civil Engineers, 25, Great George Street, Westminster, on Thursday evening, December 10th, 1896—Dr. JOHN HOPKINSON, F.R.S., President, in the Chair.

The minutes of the Ordinary General Meeting held on November 26th were read and approved.

The names of new candidates for election into the Institution were announced and ordered to be suspended.

The following transfers were announced as having been approved by the Council, viz.:—

From the class of Associates to that of Members—

Fred. H. Hadfield.

From the class of Students to that of Associates—

G. W. D. Ricks.

Messrs. A. A. Campbell Swinton, Member, and J. S. Fairfax, Associate, were appointed scrutineers of the ballot for the election of Council and Officers for the year 1897.

Donations to the Library were announced as having been received since the last meeting from the Federated Institution of Mining Engineers; Mr. R. H. Pierce, Foreign Member; Mr. E. Garcke and Mr. W. J. Hancock, Members; to all of whom, on the motion of the PRESIDENT, a vote of thanks was unanimously accorded.

The SECRETARY read the Annual Report of the Council, as follows:—

REPORT OF THE COUNCIL TO THE ANNUAL GENERAL MEETING, 10TH DECEMBER, 1896.

ELECTIONS, 1896.

The total number of additions to the register during the year has been 246, comprising 8 Foreign Members, 14 Members,

128 Associates, and 96 Students; and 58 candidates have been approved for election next month.

22 Associates have been transferred to the class of Members, and 72 Students to the class of Associates.

Deaths and Resignations.

The losses which the Institution has sustained by death, although greater than last year, are not above the average. They are as follows:—3 *Foreign Members*—L. Beckwith, W. C. A. Staring, Dr. A. Stoletow; 5 *Members*—Andrew Bell, F. S. Harwood, J. Thewlis Johnson, H. J. Vose, and Gordon Wigan; 15 *Associates*—E. W. Adamson, Edward Burn, Augustus Calder, G. F. Clements, A. T. Durrant, W. Eccles, H. L. Harris, H. C. Hodges, J. A. Kingdon, A. Langman, E. J. Lecoat, H. C. Oates, C. H. Phillips, J. R. Pickering, and C. M. Stobart; 1 *Student*—A. H. Gossage.

Mr. Staring, a past Director-in-Chief of the Netherlands Telegraphs, was one of the original members of the Institution. Mr. Andrew Bell, who was for a long period connected with the Postal Telegraph Department, had been a member for 20 years. Mr. J. Thewlis Johnson was one of the original members, and Mr. Gordon Wigan had been a member for 23 years.

Four Foreign Members, 9 Members, 21 Associates, and 7 Students have resigned during the year.

Papers.

Besides the valuable inaugural Address of the President, the following papers have been read during the year:—

Date.	Title.	Author.
Feb. 27.	High-Voltage Lamps, and their Influence on Central Station Practice	G. L. Addenbrooke, Member.
Mar. 26.	Telephone Exchanges and their Working...	Dane Sinclair, Member.
Apr. 30.	On Railway Telegraphs, with Special Reference to Recent Improvements ...	W. Langdon, Member
May 14.	Experimental Tests on the Influence of the Shape of the Applied Potential Difference Wave on the Iron Losses of Transformers	Stanley Beeton, C. Percy Taylor (Students) and J. M. Barr.

Date.	Title.	Author.
May 28.	—The Utilisation of Water Power, especially with a Small Fall, with some Examples of Plants for the Generation of Electrical Energy	A. Steiger.
Nov 12.	—The Telephone Trunk Line System in Great Britain	J. Gavey, Member.

The list is smaller than usual, owing to the circumstance of the discussion on the two papers read in November of last year having occupied two of the meetings of this year.

Annual Premiums.

In respect of the papers read during the session 1895–96 by others than members of their own body, the Council regret that only one is of that character and possesses sufficient merit to entitle the authors to a premium, viz.:—

"Experimental Tests on the Influence of the Shape of the "Applied Potential Difference Wave on the Iron Losses of "Transformers," by Messrs. Stanley Beeton, C. Percy Taylor (Students), and James Mark Barr.

To the authors of this paper they award the "Institution "Premium;" and, having regard to the fact of the authors being three in number, they intend on this occasion to increase the value of the Premium from £10 to £15.

Of the papers read at the Students' meetings the majority have been of considerable merit, and the Council have decided to present upon this occasion two Premiums of £3 3s. each. They award one of these to Messrs. E. Ray and V. Watlington for their paper on "Underground Conductors," and the other to Mr. E. B. Wedmore for his paper on "A Simple Method of "Analysing Harmonic Curves."

The Council have pleasure in making honourable mention of the following papers:—"Post Office Form of Wheatstone Bridge," by G. Lemmens; "Electricity Supply Meters," by G. W. D. Ricks.

Salomons Scholarship.

The Council have awarded a Scholarship of £50 to Mr. E. W. *Marchant*, a student of the Central Technical College.

Students' Class.

The Council have observed with satisfaction, not only the continued improvement in the character of the papers read at the Students' meetings, but also an increased activity on the part of the Students' Committee in other directions.

Your Secretary was able to arrange for visits by parties of the Students to the following works and stations during the session, viz.:—

- Messrs. Willans & Robinson's Works, Thames Ditton.
- The St. Pancras Electric Light Stations.
- Messrs. Siemens Bros.' Works at Woolwich.
- The Metropolitan Electric Supply Company's Station.
- The City of London Electric Supply Station, Bankside.
- The London Electric Supply Company's Station at Deptford.
- The General Electric Company's "Robertson" Lamp Factory, Brook Green.
- The Board of Trade Laboratory (by kind permission of Major Cardew).

To the above-named firms, the engineers of the several companies, and to Major Cardew, the Council desire to acknowledge their appreciation of the kind facilities thus afforded to the Students of the Institution.

In September last a visit by some of the Students to Switzerland was organised, by permission of the Council; and your Secretary was enabled, chiefly through the good offices of Dr. du Riche Preller, Member, and Mr. A. Steiger, to obtain for the party special facilities for inspecting many of the most important electrical and engineering works in that country, their reception being of the kindest character.

Fire Risk (Wiring) Rules.

The final revision of these rules has been purposely delayed, in consequence of the sanctioning by the Board of Trade of the use of higher voltages, rendering necessary considerable further alterations in and additions to the rules.

The Council have made a grant of money from the funds of the Institution for the purpose of enabling the committee to carry

out tests of switches, fuses, and other appliances, as now supplied by manufacturers, in order to ascertain how far these are suitable for the increased pressures.

A committee was appointed by the Council on the 28th May to consider the Council's expenditure on the direct advancement of the Electrical Industry, and whether, having regard to the annual surplus, the time has not arrived for greater expenditure in that direction, and to report.

Annual Dinner.

The Annual Dinner, which was this year held at the "Criterion" Restaurant, on the 25th November, was largely attended, the chief guest on the occasion being the Duke of Norfolk, Postmaster-General.

Annual Conversazione.

The Conversazione was this year again held in the Galleries of the Royal Institute of Painters in Water Colours, and was very numerously attended.

Building Fund.

In accordance with a resolution passed at the meeting of Members and Associates on the 6th July last, certain stocks, representing at the price of that day the sum of £3,500, have been transferred to the Building Fund account, and the interest accruing therefrom has been, and will be in future, credited to the same account, and will be invested from time to time.

It is a striking and satisfactory proof of the sound judgment exercised by your Honorary Treasurers, the late Mr. Edward Graves and Sir David Salomons, in making the Institution's investments, that the increase in value of the stocks so transferred to the Building Fund between the date of their purchase and that of their transfer was no less than £221 1s. 5d., which sum figures in the balance-sheet as profit added to the General Fund.

Annual Accounts and Financial Position.

In accordance with the resolution passed at the Ordinary General Meeting of the 12th of March last, the statement of

accounts and balance-sheet for the year ending the 31st December, 1895, as then presented, were re-cast, and were in their new form adopted at the Special General Meeting of Members and Associates held on July 6th.

Among the alterations made in the Articles of Association by the special resolution alluded to below, was one enacting that the financial year should thenceforth be taken to end on the 30th of September in each year, and that the annual accounts should in future be made up to that date, and laid before the Annual General Meeting next following. Accordingly, the statement and balance-sheet to be presented this evening only covers the nine months comprised between the 1st of January and the 30th September last.

The accountants have considered it desirable to make some further slight modifications in the form of these accounts, but they are framed substantially on the same basis as those adopted last July.

It will be seen that the receipts exceed the expenditure during this period of nine months by the amount of £887 19s. 6d., and this is without debiting the receipts with anything on account of outstanding subscriptions (the estimated realisable amount of which on September 30th was £532), as, had this been done, the accounts would have shown twelve months' income against only nine months' expenditure, with the result that the balance then shown would have been misleading. When the next year's accounts are made up this difficulty, of course, will not arise.

The sum of £801 3s. has been invested during the year on account of General Investment Fund, and £75 on account of Life Compositions.

As announced by the President at the Ordinary General Meeting of November 12th, Sir David Salomons found it necessary, in consequence of the many calls upon his time, to decline nomination this year for re-election as Honorary Treasurer.

The Council greatly regret that such should be the case, as although under the revised Articles of Association Sir David Salomons could no longer have remained a Vice-President, they had hoped by his re-election as Honorary Treasurer to continue

to have the benefit of his advice, which has hitherto proved of so much value.

Amendments in the Articles of Association.

With a desire to meet as far as was desirable in the general interests of the Institution, various suggestions which had reached them, your Council appointed a special committee to consider in what direction the Articles of Association might be amended with advantage, the result being that a series of amendments were submitted by the Council to a "General Meeting of Members "only," on the 15th of June last, and adopted by a unanimous resolution, which was duly confirmed, and thus made a "Special "Resolution" under the Companies Acts, on the 6th July.

The Council earnestly trust that these amendments will work satisfactorily, and will tend to strengthen that feeling of confidence which should subsist between the general body of members and their elected representatives.

THE LIBRARY.

REPORT OF THE SECRETARY.

I beg to report that the accessions to the Library during the year numbered 53; of these, 5 were purchased, the remainder having been kindly presented either by the authors or the publishers.

The specifications of all electrical patents continue to be supplied to the Institution, by the kindness of H.M. Commissioners of Patents.

The number of patents applied for this year, up to November 25th, was 26,425, of which 1,314, or 4·97 per cent., were electrical.*

The corresponding numbers last year were 22,442 and 1,367, or 6·09 per cent.

The periodicals or printed proceedings of other Societies received regularly are, with some few additions, the same as last year, as may be seen by the list appended hereto.

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* Up to December 31st the number applied for was 30,165, of which 1,499, or 4·97 *per* cent., were electrical.—Sec.

The number of visitors to the Library to the end of November has been 660, of whom 76 were non-members.*

The corresponding numbers last year were 743 and 116 respectively.

F. H. WEBB.
Secretary.

APPENDIX TO SECRETARY'S REPORT.

TRANSACTIONS, PROCEEDINGS, &c., RECEIVED BY THE INSTITUTION.

ENGLISH.

Asiatic Society of Bengal, Journal and Proceedings.
Greenwich Magnetical and Meteorological Observations.
Institute of Patent Agents, Transactions.
Institution of Civil Engineers, Proceedings.
Institution of Mechanical Engineers, Proceedings.
Iron and Steel Institute, Proceedings.
King's College Calendar.
Liverpool Engineering Society, Proceedings.
Physical Society, Proceedings.
Royal Dublin Society, Transactions and Proceedings.
Royal Engineers' Institute, Proceedings
Royal Institution, Proceedings.
Royal Meteorological Society, Proceedings.
Royal Society, Proceedings.
†Royal Society, Philosophical Transactions.
Royal United Service Institution, Proceedings.
Society of Arts, Journal.
Society of Chemical Industry, Journal.
Society of Engineers, Proceedings.
University College Calendar.

AMERICAN.

American Academy of Science and Arts, Proceedings.
American Institute of Electrical Engineers, Transactions.
Canadian Society of Civil Engineers, Transactions.
Franklin Institute, Journal.
John Hopkins University Circulars.
Library Bulletin of Cornell University.
Ordnance Department of the United States, Notes.
Technology Quarterly.

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* Up to December 31st the numbers were 715 and 78 respectively.

† Presented by Professor D. E. Hughes, F.R.S. (Past-President).

DANISH.

Den Tekniske Foreuings Tidsskrift.

FRENCH.

Association des Ingénieurs Électriciens sortis de l'Institut Électro-Technique Montefiore, Bulletin.

Académie des Sciences, Comptes Rendus Hebdomadaires des Séances.

Société Belge d'Électriciens, Bulletin.

Société Française de Physique, Séances.

Société des Ingénieurs Civils, Mémoires.

Société Internationale des Électriciens, Bulletin.

Société Scientifique Industrielle de Marseille, Bulletin.

LIST OF PERIODICALS RECEIVED BY THE INSTITUTION.

ENGLISH.

Cassier's Magazine.

Electrical Engineer.

Electrical Plant.

Electrical Review

Electrician.

Electricity.

Engineer.

Engineering.

English Mechanic and World of Science.

Illustrated Official Journal, Patents.

Indian Engineer.

Industries and Iron.

Invention.

Lightning.

Nature.

Philosophical Magazine.

AMERICAN.

Electrical Engineer.

Electrical Review.

Electrical World.

Electricity.

Journal of the Telegraph.

Physical Review.

Scientific American.

Street Railway Journal.

Western Electrician.

FRENCH.

Annales Télégraphiques.

L'Éclairage Électrique.

L'Électricien.

L'Industrie Électrique.
Journal de Physique.
Journal Télégraphique.

GERMAN.

Annalen der Physik und Chemie.
Beiblätter zu den Annalen der Physik und Chemie.
Electrotechnischer Anzeiger.
Electrotechnische Zeitschrift.
Verhandlungen des Vereins zur Beförderung des Gewerbfleisses.
Zeitschrift für Elektrotechnik.
Zeitschrift für Instrumentkunde.

ITALIAN.

Giornale del Genio Civile.
Il Nuovo Cimento.

The PRESIDENT: I do not know that any words of explanation are required from me with regard to this Report, and therefore I will simply move—"That the Report of the Council, as just read, "be received and adopted, and that it be printed in the Journal "of the Proceedings."

Sir HENRY MANCE: I have much pleasure in seconding the motion.

The PRESIDENT: Before putting the motion, I shall be happy to hear any remarks which members may desire to make in reference to it.

Mr. CAMPBELL SWINTON, Mr. R. S. ERSKINE, Mr. PARSONE, and Mr. CHARLES BRIGHT spoke on the desirability of holding the Annual Conversazione in a more commodious place than hitherto, and of exhibiting scientific apparatus and experiments on the occasion.

Mr. C. E. GROVE suggested that the sessional year should correspond with the financial year.

Mr. C. B. CLAY thought that measures should be taken for a better supply of papers and the earlier issue of advance proofs.

Major FLOOD PAGE asked for fresh information as to the general lines on which the Committee on the Wiring Rules proposed to carry out the tests alluded to in the Report; and Mr. ERSKINE spoke on the same subject. Major PAGE also suggested the

desirability of affiliating the colonial electrical societies with the Institution.

Mr. E. Manville advocated the issue of diplomas or certificates of membership.

The President replied to the several speakers, stating that many of the suggestions made had already occupied the attention of the Council, and that any others should be duly considered.

Mr. Crompton, as chairman of the Wiring Rules Committee, replied, by request of the President, to Major Flood Page's inquiries in reference to the proposed tests.

The motion for the adoption of the Report was then put, and carried unanimously.

The President: It is now my duty to move—"That the "statement of accounts and balance-sheet for the nine months "ending September 30th, 1896, as just presented, be received "and adopted." Those accounts, I think, have already been in the hands of you all, and therefore it is not necessary for us to have them now read.

Mr. Esson: I have much pleasure in seconding the motion.

The President having asked if any member had questions to ask or suggestions to make in reference to the accounts,

Major Flood Page said that he desired to call attention to what seemed to him the large proportion which the cost of publication and issue of the *Journal* bore to the total income of the Institution, and suggested that a considerable saving might possibly be effected by following the example of another institution to which he belonged, and whose Journal of Proceedings was only issued to those of its members who intimated their desire to receive it.

The President: Major Flood Page's suggestion shall receive due consideration.

The motion for the adoption of the statement of accounts and balance-sheet was then put, and carried unanimously.

Professor Silvanus Thompson: I rise, Sir, to move a resolution which I hope will be unanimously accepted by the members of this Institution. We owe a very great debt indeed to our kind hosts the Institution of Civil Engineers for the benefit which we enjoy

of holding our meetings in their rooms. We have enjoyed that privilege for many years, and until we are in a position of having a building of our own I do not think we could possibly be better accommodated than we are in this establishment. Not only do we enjoy the use of this Hall, and of the Council Room for the meetings of our Council, but we have the use of the rooms below for refreshments, and we have the services of the attendants who are in the employ of the Institution of Civil Engineers. Further than that, we pay nothing for any of this accommodation; we do not even have to pay for the consumption of electric energy for the light during our meetings; and we are very obviously indebted in a very strong pecuniary sense to the Institution of Civil Engineers for these privileges which we enjoy. The only thing we have to pay for is the tea and coffee which we consume after our meetings. Under these circumstances we should be ungrateful indeed if we did not very heartily thank the Institution of Civil Engineers for their continued courtesy to us, and the more so because they have recently spent such very large sums in beautifying their establishment and allowing us to participate with them the enjoyment of the great improvements which they have made. I should like, in moving the vote of thanks to them very heartily, to do it in such a form as will enable us to tell them how much we appreciate those improvements and congratulate them thereon. The resolution I have to move is—"That the members of this Institution hereby desire to record "their high appreciation of the continued kindness and liberality "of the President, Council, and members of the Institution of "Civil Engineers in allowing the meetings of this Institution "to be held in their lecture hall, and further desire to con-"gratulate them upon the completion of their magnificent new "building."

Mr. MORSE: In seconding that resolution, the only thing that I think Professor Thompson has omitted to say is that we also have the advantage of gazing upon the portraits of distinguished Engineers who have filled the office of President of the Institution of Civil Engineers, and thereby encouraging us to hope that some of us may in a similar manner have our portraits placed in this

hall or in the hall to be built for the Institution of Electrical Engineers.

The resolution was carried unanimously.

Mr. FRANK BAILEY: I have much pleasure in moving—"That "the thanks of the Institution are due to the Local Honorary "Secretaries and Treasurers for their kind services during the "year." I think all the members will see from our list of members that we are well represented in no less than 23 foreign countries and our colonies by men of prominence in their respective countries, and who do their work not only remarkably well, but who do it so cheerfully. I think, therefore, that the least we can do on this occasion is to give them a hearty vote of thanks for their past services, and to express the hope that we may continue to receive similar services in the future.

Mr. SINCLAIR: I have very much pleasure in seconding that resolution.

The resolution was carried unanimously.

Mr. CROMPTON: I rise on a matter which has caused me personally considerable regret, viz., that one of the oldest members, and one of our most valued Local Honorary Secretaries, Mr. John Aylmer, who has represented us so long in France, has been compelled by ill-health to retire from that position. Now a great many in this room have, like myself, had the pleasure of meeting Mr. Aylmer and of profiting by his kindness, especially on the occasions of the two Exhibitions that were held in Paris. At the first, almost an epoch-making Exhibition, of 1881, it was, that the activity, the kindness, the hospitality of Mr. Aylmer impressed themselves upon everybody who came in contact with him; and the same might be said in regard to the Great Paris Exhibition which was held a few years later. I think we should not let this occasion pass without letting Mr. Aylmer know how deeply this Institution regrets the loss of his services, and that those services have been very highly appreciated by us. I do not wish to labour this subject, although I could say a very great deal more. I am quite certain that many in this room can reiterate every word that I say, and therefore it is unnecessary for me to enlarge upon the subject. I accordingly beg to move—"That the members desire to express

"the great regret with which they hear of the relinquishment by "Mr. John Aylmer of the office of Local Honorary Treasurer and "Secretary in France, in consequence of ill-health; and they wish "at the same time to assure him of their high appreciation of the "unremitting attention which he has so kindly given to the "interests of the Institution during the 22 years he has held the "position of its representative in that country."

Mr. H. EDMUNDS: I beg to second the motion which Mr. Crompton has so very well put. I am sure I am expressing the feeling of those who have had the pleasure of knowing Mr. Aylmer when I say that by his resignation we lose not only a very good officer of the Institution, but also a very good friend. Mr. Aylmer in 1881 did a great deal for the electrical engineers from this country who were gathered together in Paris for the Exhibition, and I feel with Mr. Crompton that we ought not to lightly pass over his services. In seconding what Mr. Crompton has said, I would suggest that a suitable letter indicating the feeling of the meeting should be sent to him, to show that this is not a mere formal compliment, but the expression of our very sincere regret at losing his services—a regret rendered all the greater by reason of the cause of his resignation.

Mr. WEBB: (Secretary): The kind services rendered by all our Local Honorary Secretaries and Treasurers naturally come more prominently before me than before you gentlemen, many of whom are scarcely aware how much time they devote to the interests of the Institution. In the case of Mr. Aylmer, without making any "invidious comparisons," I may safely say that there is no Local Honorary Secretary who has given more kind attention than he has done. In fact, it would be impossible for anyone to be more zealous or to be kinder than he has been upon every possible occasion. Wherever an introduction was wanted to anyone in Paris, he was always willing to give or obtain it. If any special publication was wanted, we could always rely upon him to procure it. Even during the past 12 months, when he has been in a very sad state of health, he has helped us in many ways; and even so late as yesterday I had evidence of his kindness, for notwithstanding his

present condition he has taken a great deal of trouble in procuring for the Library some special numbers of a journal which I had failed to obtain after various attempts in several quarters.

The resolution was carried unanimously.

The PRESIDENT: My next duty is one which I may say is in a measure pleasurable, and yet it is not without its element of pain; it is to move—"That the best thanks of the Institution are "due to Sir David Salomons, Bart., Vice-President, for his kind "and very valuable services during the year as Honorary "Treasurer, in which capacity the members much regret he is "unable to continue to act." I am sure I am only expressing the feelings of all his colleagues when I say that those who have worked with him now for some years during which he has been our Treasurer very deeply appreciate the ability and the care with which he has watched over our finances. Not only that, but as a Member of Council he has always been ready to aid us with his advice and judgment, which were of great value to us owing to his very large and varied experience. We all greatly regret to lose his help as Treasurer, although we cannot but recognise that his many and increasing engagements must have made it more and more difficult for him to give up so much of his very valuable time to us.

Mr. BRIGHT: It gives me very great pleasure to second the resolution.

The resolution was carried unanimously.

Sir HENRY MANCE: I have much pleasure in proposing—"That the thanks of the Institution are due to Mr. F. C. Danvers "and Mr. Augustus Stroh for their kind services to us in acting "as Honorary Auditors." I think I have had the pleasure of moving a similar vote of thanks on previous occasions—so many years ago that I have forgotten how long. It is only the members of your Finance Committee who can thoroughly appreciate the time and attention which your Honorary Auditors so readily devote to the Institution. I trust that these familiar names will remain on the list of officers of this Institution for many years to come.

Mr. RAWORTH: I have much pleasure in seconding the motion.

The resolution was carried unanimously.

Mr. DANE SINCLAIR: I have very much pleasure in moving that we give a hearty vote of thanks to Messrs. Wilson, Bristows, & Carpmael for their services to the Institution as Honorary Solicitors during the year which has passed. We like to be able to say that we are in that condition where our Solicitors' duties have not been as much required as perhaps they might be under other conditions. In other words, so far as I know, we have not been at law with ourselves or with anybody else; and as long as our Solicitors are able to keep us in that unique position, so long is it our duty to give them a hearty vote of thanks.

Mr. RAWORTH: I should like to second that motion also.

The resolution was carried unanimously.

The PRESIDENT: It is my duty to announce the report of the scrutineers that the following gentlemen have been elected as Council and Officers for the year 1897:—

President:

Sir HENRY MANCE, C.I.E., M. Inst. C.E.

Vice-Presidents:

ROBERT KAYE GRAY, M. Inst. C.E.
Professor S. P. THOMPSON, D.Sc., F.R.S.
Professor JOHN PERRY, D.Sc., F.R.S.
JOSEPH W. SWAN, F.R.S.

Ordinary Members of Council:

S. L. BRUNTON.
G. VON CHAUVIN.
HENRY EDMUNDS.
Professor J. A. EWING, F.R.S.
W. P. J. FAWCUS.
S. Z. DE FERRANTI.
Professor J. A. FLEMING, M.A., D.Sc., F.R.S.
Major R. HIPPISLEY, R.E.
W. E. LANGDON.
E. MANVILLE.
J. S. RAWORTH, M. Inst. C.E.
DANE SINCLAIR.
JAMES SWINBURNE, M. Inst. C.E.
HERBERT TAYLOR, M. Inst. C.E.
CHARLES HENRY WORDINGHAM.

Associate Members of Council:

Captain W. P. BRETT, R.E.
H. W. MILLER.
SYDNEY MORSE.

Honorary Auditors:

FREDERICK C. DANVERS. | AUGUSTUS STROH.

Honorary Treasurer:

Professor W. E. AYRTON, F.R.S., Past-President.

Honorary Solicitors:

Messrs. WILSON, BRISTOWS, & CARPMAEL, 1, Copthall Buildings, E.C.

Mr. J. S. RAWORTH moved that a hearty vote of thanks be accorded to the President and Council for the admirable manner in which they had given effect to the views and wishes of a very large number of members by obtaining a revision of the Articles of Association. He thought that the proceedings of that evening afforded ample proof of the benefit to be derived by confining the business of the Annual General Meeting to the internal affairs of the Institution.

Major FLOOD PAGE, in seconding the motion, desired to congratulate the President and Council on the result of their labours in dealing with the suggestions that had reached them from various quarters in reference to the Articles.

The motion was unanimously carried.

The PRESIDENT, in acknowledging the vote, said that he and the Council had very carefully, and he might say honestly, considered all the suggestions which had been brought before them in reference to the revision of the Articles, and it had been a great satisfaction to them that the amendments they had recommended were unanimously adopted and approved at the two Special General Meetings held in June and July. He felt little doubt that those amendments would prove of great benefit to the Institution, and at all events they would enable the members to feel that whatever is done will now really be done by the will of the majority. That was a primary element in securing confidence in the management of an Institution such as this.

He thanked them heartily, on his own behalf and that of the Council, for their kind acknowledgment of what had been done.

The meeting then adjourned.

ORIGINAL COMMUNICATION.

FIELD TELEGRAPHS WITH THE CHITRAL RELIEF FORCE, 1895.*

By F. E. DEMPSTER, C.I.E., Member.

A few words on the actual equipment and general arrangements are necessary before describing the work on the campaign.

The whole of the Indian field equipment is designed for mule carriage, and, as far as possible, everything is divided up into 40-lb. loads, or quarters of a mule load. By this means hand transport is made possible where other transport is unavailable. It has to be remembered that on campaigns beyond the Indian frontiers roads are non-existent, and that the country traversed is, as a rule, hilly, and very often covered, in addition, with dense forests. Cart transport, which can always be calculated on for European conditions, cannot be depended upon when once the Indian frontier has been crossed. All articles must therefore be so arranged as to form loads, or convenient fractions of loads, for such transport as may either be obtained locally, or taken with the expedition. Experience has shown that 40 lbs. is the most convenient unit. The annexed table shows approximately the loads carried by the various kinds of transport met with :—

Man	40 to 50 lbs., rarely 60 to 80 lbs.
Donkey	100 lbs. to 160 lbs.
Bullock, mule, or pony ...	160 lbs.
Camel	500 lbs.
Cart	1,200 lbs.
Elephant	500 lbs.

Light iron tubular posts, in four, or sometimes five pieces, were used; the different portions being packed inside one another for convenience of transport. They carry a light cast-iron cap, and

* Several interesting photographs accompanied this communication, but, unfortunately, it was not found practicable to reproduce them.—ED.

each complete post with insulator and cap weighs abont 40 lbs. Four consequently form a mule load. Brackets are carried separately; they are of cast iron, and are adjustable (by means of a semicircular back, with screw ends and nuts) at various positions on the upper tube. Insulators are of porcelain; one is always kept pushed into the inside of the tubes. The wire is of iron, galvanised, and weighs 150 lbs. or 300 lbs. per mile. The instruments and office equipments are carried in boxes, painted red—a familiar sight now on every portion of the Indian frontiers. They are lettered from A to F, and weigh, when full, 80 lbs. each, two forming a mule load. The instruments consist of a relay, sounder, transmitting key, and connections for translating through and terminal working, all fitted on one baseboard. Two of these are carried in one A box.

Batteries consist of a small portable form of Minotto, which has been selected on account of its great constancy. Their weight, however, is against them, and many experiments have been made with dry cells, which in future campaigns will probably be largely used. The remaining boxes contain stationery, message forms, lamps, candles, portable sounder and battery, wire for office connections, small tools, &c. Tents, weighing, with an office table, 160 lbs., are also provided.

Line tools, such as crowbars, phowras (the Indian spade), blocks and tackle, blacksmith's anvil and appliances, are all provided in boxes or packages weighing 80 lbs. each.

The supervising staff is composed of officers selected from the Civil Telegraph Department and from specially trained officers of the Royal Engineers. The ordinary work of the Department gives the best training for field work that a man could have. In the various wild and unhealthy parts of India, which are constantly being opened out by railways, the telegraph invariably is there too. All the hardships, all the trials, all the difficulties, with the sole exception of an armed enemy, that are encountered on an expedition, have to be grappled with on nearly every construction work. This training applies to the line establishment as well as to their officers, and the consequence is that the staff sent on an expedition are experts in jungle devices, and generally in "making

"bricks without straw." This is most important, for on light hastily constructed lines absolutely the best workmanship is indispensable if success is to be assured. The signalling staff is largely recruited from the European regiments, who in times of peace furnish men to be trained in the various training classes scattered throughout India. A certain number of selected civilian signallers are also sent for work in the large offices in a system, where their more thorough training and longer experience enables them to cope with heavier traffic then their soldier *confrères.* The actual workmen are recruited as near the base of operations as possible. There is seldom any difficulty in getting a couple of hundred men, the majority of whom have worked on the usual maintenance or construction of the lines in the district.

At certain selected stations depôts of military field telegraph stores are formed, from the most convenient of which stores are sent whenever an expedition has been ordered. An integral part, though entirely under military management, of field telegraph work, is the heliograph staff and regimental flag signallers, or "flag-waggers," as they are familiarly termed. This army signalling service has been brought to a very high state of efficiency, and takes a great deal of petty work off the heavily burdened wires. It has far greater mobility than the telegraph service, and can therefore better be used on the actual field of action. It may be laid down that there is no advantage gained in laying a telegraph line that has immediately to be picked up again, or which cannot be to a certain extent protected by patrols. There is no doubt that the inconvenience caused by having to depend entirely on helio and flag signalling for a short time, is not to be compared with that caused by serious interruption of the telegraph service, after it has once been introduced.

The communications required by an army in the field will necessarily vary considerably with the scope of the intended operations. For a division they may, however, be thus generally summarised:—

(*a.*) A line from the Commander-in-Chief in India to the headquarters of the Field Force. This is the channel of communication with the source of all supplies, and gives the headquarters of the

Army in India administrative and political control over the army in the field.

(*b*.) A line from the general commanding the Field Force to each of his brigadiers and to his base. This is to enable him to administer all the forces under his command.

(*c*.) A line entering every post on the line of communications, primarily for convoy work, and secondarily for general work.

(*d*.) Camp lines, generally worked by telephone, between various portions of the same camp. These save orderlies galloping about, and are of great service generally.

(*e*.) Special connections, such as bell alarm lines, taken out by pickets, and in connection with quarter guards, by means of which notice of movements of the enemy may be given; and alarm wires to keep off rushes or "rifle thieves."

I do not mention means of communicating established during action, because all this is provided by the army signallers.

That sufficient wire accommodation should be provided is highly important. Interruptions are certain to occur. The enemy will do his utmost to cut up the line (generally returning small fragments in the shape of slugs into the camps). If the lines are always heavily loaded with traffic, each interruption means possibly hours of delay to important messages. Only those who have actually experienced it can realise how the worst interruptions invariably occur when the most important military and political telegrams are awaiting transmission. It is rarely possible in an enemy's country to try to repair damage during the night; precious hours, therefore, slip by while the pile of delayed messages rises higher and higher.

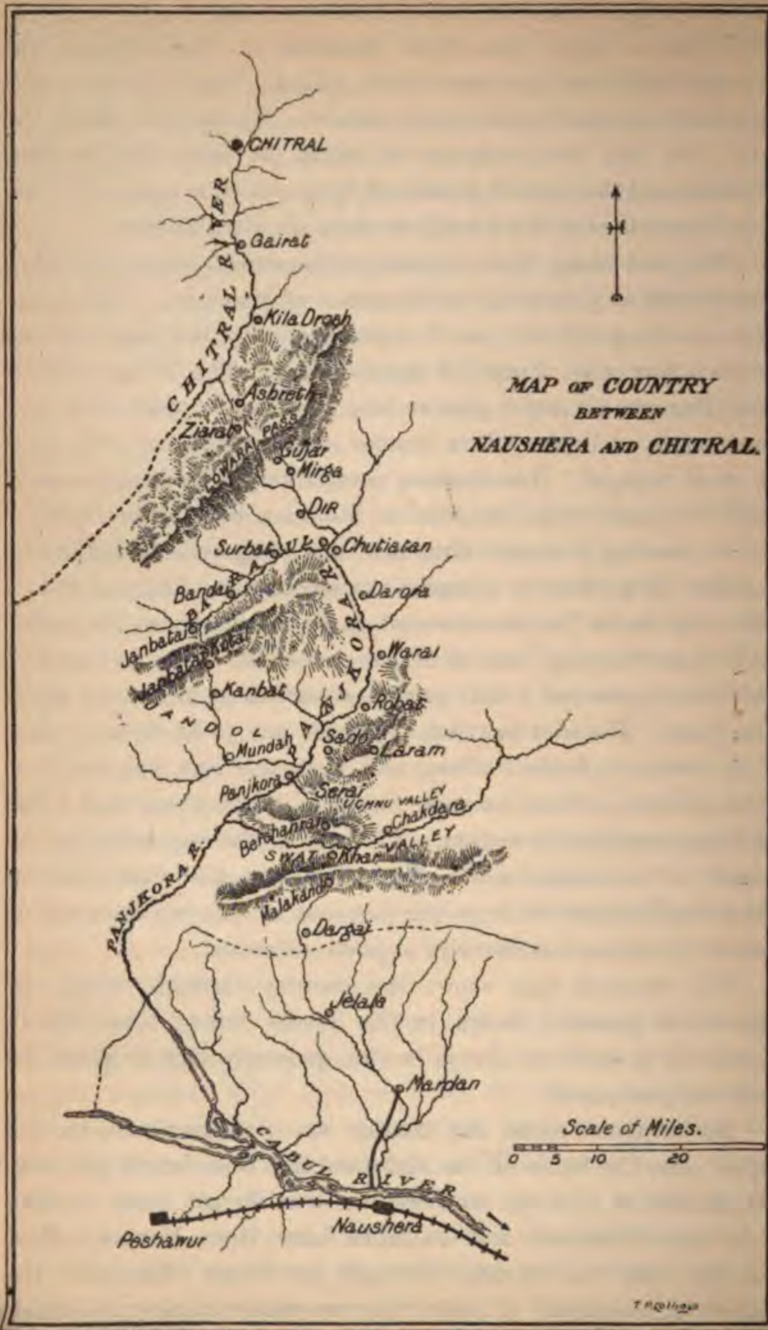
Mobilisation was ordered on the 18th of March, 1895, and by the 25th sufficient material for a line of two wires 200 miles in length, together with equipments for 20 offices, complete with tools and all requisites, as well as the necessary signalling and line establishments, were collected at Naushera, a little railway station some 25 miles from Peshawur, and 16 miles from the actual base of operations, Hoti Mardan. The staff consisted of six officers, 86 signallers, 46 native line establishment, and 150 *workmen*. At the same time the staff at Rawalpindi, the chief

military depôt, Naushera, and Hoti Mardan, was largely increased. The line—a single wire—from Naushera to Hoti Mardan was reconstructed, and two more wires added. One wire was quadruplexed between Naushera and Lahore. By the 31st March the field line had been run up to Jelala, 13 miles beyond Hoti Mardan, and the greater portion of the stores and equipments had also been collected there ready to move on when allowed.

The first thing that required arrangement after everything had arrived at Naushera was the means of transport. This is the ever-recurring difficulty, as, of course, the troops and their food and ammunition must always be supplied first. The Military Transport Department could give no help, but luckily there were local contractors available, with a limited number of camels, who were at once engaged. Two working parties were constituted—one to push on ahead with one wire as fast as allowed; the second to follow erecting a second wire, and improving and strengthening the line. The officer in charge of the second party had also to look after the stores for the advanced party, to supervise the traffic, and to see that each section of line as he left it was in thorough order and possessed a duly organised staff to maintain and patrol the lines. The idea was that the traffic was to be disposed of as if in ordinary Indian offices, and that the line was to be so strengthened as to be no more liable to interruptions than a line of the general Indian system. This was at first impossible, as the record of interruptions will show; but that the work done was good may be inferred from the fact that in only one interruption caused by storms was the wire or posts unbroken.

The attached map shows the country through which the expedition passed. Except in the Jandol Valley, Umra Khan's home, the ground was always broken, generally very hilly, and on occasion precipitous.

No advance beyond the frontier was permitted until the 3rd April, after the battle of the Malakand had been fought and won. On the 4th of April the wire was run into Dargai, about 4 miles from the Malakand and 24 miles from Hoti Mardan. Next day the wire was extended through the wheat fields into the valley, in the midst of which the enormous number of camels


MAP OF COUNTRY
BETWEEN
NAUSHERA AND CHITRAL.
CHITRAL
CHITRAL RIVER
Gairat
Kila Drosh
Asbreth
Ziarat
LOWARAI PASS
Gujar
Mirga
DIR
Surbat
Chutiatan
Bandai
Darora
Janbatai
Janbatai Kotal
Warai
Kanbat
Robat
PANJKORA R.
Mundah
Sado
Laram
Panjkora
Serai
UCHNU VALLEY
Chakdara
SWAT
VALLEY
Malakand
Dargai
Jelala
Mardan
Scale of Miles.
0 5 10 20
CABUL RIVER
Peshawur
Naushera

and mules carrying supplies for the troops had got wedged in a solid mass. The only feasible track up the pass was covered with animals. To take the line up by or near the road was therefore impossible, and was, moreover, forbidden. The line had to go up somehow; so, skirting the mass of animals, the working party proceeded up the valley, hoping to find a way up by a footpath. Two miles further a sort of goat track zig-zagging up the face of the almost precipitous cliff was visible. It was quite impassable for the laden camels, who were consequently at once unladen. Then the working party clambered up, erecting the wire and posts as they went, and carrying with them coils of wire, posts, tools, and one office equipment. The ascent was about 1,000 feet, and the heat was intense; so it may be imagined the party was proportionately glad to reach the summit—only to find, however, they had to cut their way through a thick wood of wild olive before they could reach the Malakand Camp. This hacking through the trees was the hardest job of all, and the wire was not got through till nearly 5 p.m. The office tent was then rapidly erected, red boxes were opened, the instruments rigged up, and "Dargai" called for. In a few minutes the answering call came, report of "opening" was despatched, and then the whole party had to trudge back the 5 miles to Dargai, as it was impossible to bring the camp on that day. The next three days' work from the top of the Malakand was very easy. The headquarters were caught up at Khar, 4 miles further, where an office was opened; and then the line was taken through the fertile Swat Valley to Chakdara, the crossing of the river 6 miles from Khar, and 39 miles from the base. The river at the crossing was in four channels, running very strongly and chest-deep. The Swat is a snow-fed stream, and, like all such, swells very much after mid-day, owing to the melting snow. The fords altered in depth every hour, as the animals passing over displaced the shingle. The line was got over without very much bother, except that one camel was lost. As the weather appeared very unsettled, a small party stayed at the fords, and every effort was made to push on telegraph stores across, so that if the river came down in high flood there should be some material to go on with. The time

was well spent, as 30 miles of material and three office equipments were got across. Leaving Chakdara, the line was pushed on up the Uchnu Valley, over the Katgolai and Kamrani Passes, into Sado, on the Panjkora River, 19 miles further, where the headquarter camp was. The line reached Sado on the 14th April, the day after the fight at the Panjkora in which Col. Battye, commanding the Guides, was killed. Further progress was again stopped till a bridge over the Panjkora River could be made.

While halting at Sado the field lines were specially utilised for a long conversation between Sado and Simla by the Commander-in-Chief and Sir Robert Low, a distance of over 600 miles. For the last hour or so there was a heavy thunderstorm, with torrents of rain, and the lightning interfered with the instruments a good deal; but the communication was distinctly good, and afforded a very gratifying proof of the efficiency of the new field line.

The second wire in the meantime had been steadily pushed on, and reached Malakand on the 8th, Khar on the 9th, and Chakdara on the 14th April. The crossing over the Swat River had been made as safe as possible—most satisfactorily so, as the light field posts, with well-made cairns round them, withstood all the summer floods, without a single interruption.

On the 18th April a fresh start was made across the Panjkora, up the Jandol Valley; and on the 19th Umra Khan's capital, Mundah, 8 miles further (71 miles from the base) was reached. The night the telegraph office was opened at Mundah the staff had their first taste of what was afterwards of almost nightly occurrence, namely, "sniping," a sentry being killed just outside the telegraph tent. On all the Indian frontiers "sniping" is a well-known word, and denotes the custom the tribesmen have of firing into the camp after dark. The actual percentage of hits is luckily low, but the annoyance caused is great, especially to men engaged in signalling work, which must be done correctly.

On the 20th the line was extended to Kanbat, at the foot of the Janbatai Pass, 12 miles from Mundah. The country was exceedingly easy, the 12 miles being erected in eight hours; this was the most done in one day. This completed 83 miles of line. The Janbatai was a range towering nearly 4,000 feet above Kanbat,

with the merest trace of a path over it. Camels were therefore useless, and the telegraph party were detained till they could get other means of transport. The first day everyone who had any mules was begged or cajoled into lending them, and 2 miles of line were erected. Then, by the good services of the Political Officer, an unwashed horde of the natives of the country were enlisted for carriers—strange, wild-looking tatterdemalions, who were at least as curious to us as we to them. It was explained carefully that each man would be paid after his day's work, on his production of a small numbered gun-wad, given to each with the loads. They did not believe this in the least: the *corvée* is no unknown thing beyond the frontiers, and that they should be paid, when they could be forced to work for nothing, seemed absurd. A few only, therefore, of the more enterprising spirits did turn up, and, with an absurd air of not wanting to be made fools of, presented their wads. To their intense amazement each man got his silver eight-anna bit. That was enough—the British rupee is the true *pax Britannica*—next morning more men than we wanted turned up: old men, lusty youths, lads in their teens, all anxious to get a picking out of such an easily worked mine.

Running the line up to the head of the pass was a very arduous undertaking; the ravines that had to be crossed were many hundred feet deep, and getting the stores distributed and the wire strained was as difficult work as could be imagined. The line reached the top of the pass, 6 miles from Kanbat—a cold, bleak spot—on the 22nd April. On the 24th the headquarters again moved on, and the line was carried the same day 9 miles further, to Bandai, in the Baraul Valley. Here the scenery changed completely. The hill sides were clothed with big holly bushes. The fields were full of violets and wild strawberries. The track was bordered with bushes of hawthorn in blossom, eglantine, and clematis.

Each little village was embowered in fruit trees—apples, walnuts, and cherries; grapes grew everywhere in great abundance.

The hill sides were very precipitous, and the holly and other undergrowth was so dense that getting the line up was a continual

worry. Luckily, every man had a kukri, with which a way was hacked. It was not, however, until the 27th April that Dir, at mile 115, was reached, when another halt had to be made.

During this time the second party reached Panjkora on the 20th April, completing the second wire 63 miles from the base; and, as it was decided not to extend the second wire any further for the time being, they devoted their energies to putting the whole line in thorough order, as it required alteration in some places where new roads had been made.

The halt at Dir was a very welcome one, for many reasons. The working party were all the better for a rest, and were able to get their clothes looked to, their tools repaired, and accounts settled up. Up to this date—the 27th of April—the location of heads of brigades and departments had not been settled, and the traffic in the various offices fluctuated to such an extent, as these officers moved about, that no general system of working could be laid down. Now, however, general orders could be issued, and a complete scheme for working the line was introduced. This will be explained later on.

The Government then decided that the field line from Hoti Mardan to Khar, in the Swat Valley—that is, the first 33 miles of the double-wire line—should be replaced by a permanent line carrying three wires. It was also decided at the same time that only one wire should be carried on from Dir to Chitral. This necessitated rearranging the working parties, as a very strong party was no longer required with the advance. Twenty-five men and five of the line establishment were therefore sent back to Hoti Mardan.

On the 1st May work again commenced beyond Dir up the precipitous valley leading to the famous Lowarai Pass. In the 12 miles from Dir to Gujar, the post at the foot of the Lowarai Pass, the ascent is from under 5,000 feet to nearly 9,000 feet, or very nearly 1 in 15 the whole way. The hills rose precipitously out of the valley, and erecting a line up the valley was very hard work. The track was only a few feet wide, and, as a rule, very steep and uneven. It was extremely difficult to find foot-hold on which to work, and the difficulty was aggravated by the thorny

shrubs scattered over the hill sides. Six miles a day was the utmost that could be erected, and the men were utterly fagged out by the time they reached camp. The line reached Gujar on the 2nd of May. This camp is 8,850 feet above the sea, and, in the beginning of May, was perched on some bare grey granite rocks left uncovered by the snow, which filled the base of the valley, and exposed to the piercing winds that whistled down from the top of the pass. Next day the real ascent of the pass was commenced. Gujar is about 2½ miles from the crest of the pass, and in that distance 1,650 feet is ascended—an average grade of 1 in 8. The road kept on the left side of the valley, just above the snow, but crossing snow at every little subsidiary valley, of which there were many. Half a mile from the top the valley merged into the hill side, and the track went straight up through the deep snow.

Arrived at the top, the descent on the other side commenced with a steep snow glissade, extending downwards for several hundred feet, and much steeper than the roof of any ordinary house. The mules had all to be unladen at the top, and driven down. Every now and then their sharp hoofs would penetrate through the frozen crust of snow, and the hapless mule would sink up to its girths. The stores were taken down, or rather dragged down, on the surface of the snow. At the foot of the glissade there was a dense pine forest, in which it was impossible to erect posts. The day's work only brought the wire about 4 miles, to the foot of the glissade. Next day it was erected into the first camp beyond the Lowarai, called Ziārat, 6 miles from Gujar. The pine forest extended about 7 miles altogether, to the next camp, Ashreth. Among the trees only tree-brackets were used, and no posts at all. The trees grew so thick, however, that a good deal of lopping had to be done, to keep the wire clear from leaf contacts. The great difficulty was to get the wire down low enough. The natural slope was as great as on the other side, and it happened over and over again that the men uncoiling the wire found they could not get down to the next bracket, and had to recoil and uncoil again. It was impossible to see clearly 0 yards ahead, and the line had to zig-zag down near the path,

and as suitable trees could be found. From the date of reaching Ziārat till the 16th of the month the whole party was delayed for want of stores. Camels could not pass the Janbatai Pass, so all stores had to come on from there by means of mules, donkeys, or coolies. Nothing but mules could cross the Lowarai, and, as the number of mules was limited, only small quantities of telegraph stores could come on at a time. The work therefore progressed very slowly. One day three or four miles of wire would arrive, then a mile or two of posts, and so on. Once the forest was passed no trees were to be found, the Chitral Valley being very bare, except just round the villages. Posts were therefore a necessity.

In the meantime it was found that the telegraph traffic at Mundah, where the commissariat headquarters were located, was so heavy that a second wire was needed. On the 8th May, therefore, the second wire, which had been stopped at Panjkora, was extended to Mundah, a distance of 71 miles from Hoti Mardan.

On the 9th May an office was opened at Kila Drosh, about 20 miles from Ziārat and 30 from Chitral. This place is now the headquarters of the force remaining at Chitral. Gairat, the next post, 9 miles from Kila Drosh, was reached on the 13th. About 3 more miles of wire and 8 miles of posts were erected, and this exhausted the supply of stores. At last, on the 15th May, sufficient stores crossed the Lowarai, greatly to everyone's satisfaction.

Arrangements were all ready, and the stores reached Ashreth the same day. An early start was made the next morning, and everything was safely landed in Gairat about midnight. The last 9 miles were covered in the dark, and the way the mules managed to negotiate the almost precipitous paths in the dark is a mystery. Only one mule fell and threw his load, and that, curiously enough, occurred on about the only piece of level ground they crossed; he fell over a big rock. Just before reaching Gairat the path was supported on a rough scaffolding on the face of a particularly steep cliff, which, when seen in the daylight, seemed peculiarly uninviting and dangerous. Next day—the 17th May—a fresh start was made. An officer was sent on to Chitral, and he got the office all ready, having begged a couple of miles of very light wire from

the bridging stores, with which he spanned the river. The construction party followed, having great difficulty in passing the villages, which are embosomed in fruit trees. The valleys running into the main stream had almost precipitous sides, and were full of vegetation, over the top of which the wire had to be taken. Finally, after a very hard day's work, all the wire was expended about 2 miles short of Chitral, in the dark. No one exactly knew where the road was, or where Chitral was, except that it was on ahead. All the party was then collected together, the field cable drums brought up, and a few torches of pine splinters lit. Then, on the party trudged, going as straight as possible, through fields of wheat, tumbling into ditches, and skirting villages, laying the cable as they went. Then, an apparently interminable graveyard was entered, and finally a flickering light ahead appeared, borne by some of the men sent on in the morning, who had been patiently waiting for the party to arrive, instead of coming to look for them! The wire was thus triumphantly borne in to Chitral, 176 miles from Hoti Mardan, about midnight, and a few hours afterwards communication was established with the next stations.

The construction in the Chitral Valley was the hardest piece of work met with, owing to the succession of precipices along the face of which the line had to be carried. In many places men could barely find room to stand and work. Running out the wire was in many places a very risky job; but, luckily, not a single man was hurt; the only accident that occurred being the loss of a wire reel over a precipice near Kila Drosh.

By the 19th of May all the permanent material for the line from Hoti Mardan to Khar had arrived, and work was started. Except over the Malakand Pass, where the new line followed the road that had been made subsequent to the advance, the alignment of the field line was followed. The work had to be done using for two of the wires the actual working wires then up, and, if possible, without interfering with communication. This was done by working in sections. Three miles of the new posts of one wire were first erected. Then one wire for that distance was c out of circuit in the field line, and the new wire
The wire just cut out of circuit was then dismantled

field posts and erected on the new posts, and was in its turn cut in in the place of the second field wire, which was then cut out, dismantled, and re-erected on the new posts. The field posts were then dismantled and sent in to the nearest stations. The work was one that required care, but there would have been no need of any special remark had it not been for the intense heat, which entailed great suffering on the working party. Work had to be entirely stopped between 10 a.m. and 4 p.m., and even at the latter hour the thermometer was generally over 103° in the shade. The work on this permanent line was completed into Khar—33 miles—on the 11th of June, and the rate of progress was 3 miles a day, which, under the circumstances, was surprisingly fast.

The advanced party only stayed at Chitral long enough to replace the field cable by a line, and then marched back. The line was carefully surveyed, and strengthened and improved. Rough huts were run up for the office staff at the various stations. Linemen were left at each office, completely equipped with tools, spare stores, &c., for maintenance purposes. On arrival at the Lowarai a halt was made, and a new line run over it from below Gujar to Ziārat. On the portion free from trees stout pine posts were erected, and every endeavour was made to erect a line that would withstand the winter. It was not, however, exposed to this test, as the wire was dismantled in September.

The general commanding the field force was then in camp at Mirga, near Gujar, and his camp was joined to Dir by wire. The second wire was also extended from Mundah to Janbatai Kotal, where the "line of communications" headquarter camp was.

The next piece of work was to replace all the field posts between Gujar and the foot of the Janbatai Pass by wooden ones. After a few days' delay, arrangements were made with a local contractor belonging to Dir to supply small fir saplings. The iron posts were then sent to Panjkora, leaving only wire and insulators to be carried if withdrawal was ordered.

All these petty works kept the party continuously employed till the middle of July, when orders were received to erect a line from Sado, up the left bank of the Panjkora River, to Chutiatan,

the junction of the Baraul and Panjkora Rivers, 5 miles below Dir. Two parties started on this, one from each end, and the 45 miles were erected in seven days. The headquarter camps then moved to the Laram Pass, 13 miles from Chakdara. The second wire beyond Panjkora as far as the Janbatai Kotal was therefore no longer needed, so the party marched to the Janbatai Pass to dismantle it. On the 26th July the wire was dismantled from the pass to Kanbat—6 miles—an easy day's work. Next day every effort was made to dismantle it the whole 20 miles from Kanbat to Panjkora, but the party could not manage more than 18 miles. This was due to it being nearly all 300 lbs. per mile wire, which, at 40 lbs. to the coil, runs to between seven and eight coils of wire per mile. In dismantling, the wire was cut at the joints, then carefully coiled on reels, made fast, and then loaded on the transport animals. At the same time the insulators and brackets had to be removed, packed, and loaded on the animals.

The dismantled wire was then taken to Chakdara, and a line run up across the Laram Pass, and the third wire was extended to Chakdara from Khar. The connections as they then (31st July) stood were as follows:—Three wires from Hoti Mardan to Chakdara, 39 miles; Chakdara to Panjkora, 24 miles, two wires; Chakdara to Dir, *via* the Laram, one wire, 54 miles; Panjkora to Dir, *via* Mundah and Janbatai, 52 miles; Dir to Chitral, one wire, 61 miles.

Orders were then given that the route from Panjkora through the Jandol and Baraul Valleys to Chutiatan should be evacuated, and two parties were sent off to the Janbatai Kotal. One party commenced at Janbatai Kotal on the 7th August dismantling the line in the Baraul Valley, and finished as far as Chutiatan on the 8th. The second party commenced from the Kotal on the 8th, and dismantled the line through the Jandol Valley, and reached Sado on the 14th August. A branch line of 5 miles was then run up from Serai to Berchanrai, a camp formed on the hills looking down on the Swat River. This completed the construction in the system.

The following is a conventional diagram of the whole syste


CHITRAL FIELD TELEGRAPHS.
Conventional Diagram of System.
Chitral (4,500 ft. above sea)
15
Gairat
9
Kila Drosh
14
Ashreth
6
Ziarat
3
LOWARAI PASS (10,500 ft. above sea)
3
Gujar (8,850 ft. above sea)
2
Mirga
9
Dir
(5,000 ft. above sea)
5
CHITRAL R.
Chutiatan
Baroba
BARAUL R.
Janbatai
5
7
5
4
(7,400) Janbatai
Kotal
Surbat
6
(5,900) Kanbat
12
Mundah
8
Panjkora
JANDOL VALLEY
PANJKORA RIVER
Darora
11
Warai
12
Robat
SMALL FIGURES BETWEEN STATIONS ARE MILES.
REPRESENTS TELEPHONE CONNECTIONS.
3
Sado
12
7
Laram (6,000 ft. above sea)
8
Serai
Betchanrai
5
11
13
Chakdara
SWAT R.
6
Khar
4
Malakand
PASS (3,000 ft. above sea)
5
Dargai
12
Jelala
12
Hoti Mardan
CABUL RIVER
10
Naushera
To Peshawur
To Lahore

Table I.—Details of Construction.

Section.		Constructed.		Re-Constructed.		Dismantled.		Remaining.	
From	To	Posts.	Wire.	Posts.	Wire.	Posts.	Wire.	Posts.	Wire.
Mardan... ...	Jelala	12	24	12	36	12	24	12	36
Jelala	Dargai	12	24	12	36	12	24	12	36
Dargai	Malakand ...	5	10	5	15	5	10	5	15
Malakand ...	Khar	4	8	4	12	4	8	4	12
Khar	Chakdara ...	6	12	...	6	...	6	6	12
Chakdara ...	Serai	11	22	...	...	11	22	...	...
Serai	Sado	8	16	...	...	8	16	...	...
Sado	Panjkora ...	5	10	...	...	5	10	...	...
Panjkora ...	Mundah ...	8	16	...	...	8	16	...	...
Mundah ...	Kanbat	12	24	...	...	12	24	...	...
Kanbat	Janbatai Kotal	6	12	...	...	6	12	...	...
Janbatai Kotal	Janbatai ...	4	4	...	...	4	4	...	...
Janbatai ...	Bandai	5	5	...	...	5	5	...	...
Bandai	Surbat	7	7	...	...	7	7	...	...
Surbat	Chutiatan ...	5	5	...	...	5	5	...	...
Chutiatan ...	Dir	5	10	...	...	5	10	...	...
Dir	Mirga	9	18	...	...	9	18	...	...
Mirga	Gujar	2	2	...	...	2	2	...	...
Gujar	Ziārat	6	6	...	...	6	6	...	...
Ziārat	Ashreth... ...	6	6	...	...	6	6	...	...
Ashreth... ...	Kila Drosh ...	14	14	...	...	14	14	...	...
Kila Drosh ...	Gairat	9	9	...	...	...	...	9	9
Gairat	Chitral	15	15	...	...	...	...	15	15
Sado	Robat	12	12	...	...	12	12	...	...
Robat	Warai	12	12	...	...	12	12	...	...
Warai	Darora	11	11	...	...	11	11	...	...
Darora	Chutiatan ...	6	6	...	...	6	6	...	...
Chakdara ...	Laram	13	13	...	...	13	13	...	...
Laram	Robat	7	7	...	...	7	7	...	...
Serai	Berchanrai ...	5	5	...	...	5	5	...	...
	Total	242	345	33	105	212	315	63	135
Add Re-Construction ...		33	105	...	...	...	...	...	...
Total Constructed ...		275	450	...	...	...	...	...	...

Table I. gives details of the work done, and a few particulars that may be of interest. The method of construction of field lines differs from ordinary work chiefly in having to keep the party as compact as possible, but it is difficult to keep it within a mile. The officer in charge of the party went ahead choosing the general line, which was at once picked out with flags. The hole-diggers then commenced with crowbars, jumping the holes. The holes made are just deep and wide enough to take a man's arm easily. Simultaneously the wire is uncoiled and the animals with the posts brought as near the alignment as possible. The posts are then unpacked, a whole mule load of four being taken at a time. As each post is brought to the hole it is fitted, and the bracket and insulators fixed on. A small party of four or five men next come and fix on stays where needed. The erecting party follow, and the moment the post is up, the wire is put up and strained. The straining is done with light block and tackle, and the wire is then bound to the insulators. The joints made are twist, and at first are not soldered.

If the party has not reached camp by nightfall, field cable, 10 miles of which is always carried (on five mules), is joined on to the line wire and run out off drums on barrows carried by a couple of men. It can be laid as fast as the men can walk. The signallers are sent on ahead: they arrange with the officer commanding the camp, where the office tent is to be pitched. They pitch the tent, get the instruments and batteries ready, put on all the connections and make an earth connection, so that the moment the line reaches camp communication can be established. The officer choosing the alignment must have a good eye for country, and all the men must be thoroughly skilled. The line is, as a rule, taken as near the road as feasible, on account of ease of distribution and facility of inspection and maintenance. It is not, as a rule, practicable to cut and erect posts as the party moves on. The actual rate of work during the expedition was not high, averaging only 5 miles a day; but on only one occasion was work stopped before all the stores had been used or before camp was reached. The best day's work was 12 miles in eight hours, and further progress that day was stopped. Had it always been

possible to have enough transport, and to proceed, an average of 8 or 10 miles might have been reached.

All construction work having been completed, the next thing to be done was to make arrangements for the anticipated withdrawal of the troops, definite orders regarding which were received in the beginning of September.

This dismantlement averaged 12 miles a day, the most done in one day being 9 miles of posts and 22 miles of wire.

The field material was then stacked at Chakdara, and the party proceeded to Naushera, where it was paid off by the 15th October, after very nearly seven months' continuous work.

The amount of work done was—

Miles of wire erected	... ...	450
,, posts ,,	... ...	275
,, wire dismantled	... ...	315
,, posts ,,	... ...	212
Offices opened	... ...	29

The health of the party was good throughout. There were a few cases of illness, but only half a dozen men were invalided, and there were no deaths.

It was apparent from the very commencement of operations that the great difficulty would be to dispose of the traffic smartly. The traffic was naturally heaviest at the stations where the headquarter staff were, and at first, when the staff was always on the move, and there was only one wire, the greatest management was required to prevent the traffic getting hopelessly blocked.

Table II.—Details of Offices, showing Staff and Total and Daily Traffic.

Name of Office.	Date.		Strength of Signalling Staff.		Number of Messages disposed of while Office was open.				Average Daily Traffic.
	Opened.	Closed.	Tel. Masters	Signallers.	Sent.	Received.	Transit.	Total.	
Jelala	28 Mar.	...	1	1	3,676	3,566	404	7,646	40
Dargai	4 Apl.	...	1	1	6,536	6,807	98	13,441	74
Malakand ...	6 ,,	...	1	1	4,617	4,645	292	9,554	53
Khar	8 ,,	30 Sept.	4	10	6,579	6,825	39,316	52,720	299
Chakdara ...	10 ,,	...	1	1	7,611	8,096	350	16,057	92
Gumbat ...	13 ,,	23 Apl.	1	1	233	195	34	462	42
Serai	24 ,,	25 Sept.	1	1	3,638	3,586	3,446	10,670	69
Sado	14 ,,	24 ,,	1	1	1,748	1,418	132	3,298	72
Panjkora ...	17 ,,	15 Aug.	1	1	3,767	3,337	2,768	9,872	81
Mundah ...	19 ,,	12 ,,	4	12	7,021	7,076	42,050	56,147	484
Kanbat	20 ,,	9 ,,	1	2	2,653	2,541	1,416	6,610	59
Janbatai Kotal	23 May	8 ,,	2	4	5,832	6,526	34	12,392	159
Janbatai ...	24 Apl.	29 May	1	...	271	367	...	638	18
Bandai	24 ,,	8 Aug.	1	...	2,154	2,139	10	4,303	40
Surbat	25 ,,	28 Apl.	1	...	83	179	...	262	32
Chutiatan ...	8 Aug.	20 Sept.	1	1	728	588	...	1;316	30
Dir	27 Apl.	20 ,,	2	14	9,704	11,014	22,752	43,470	296
Mirga	16 June	8 ,,	1	1	2,491	2,796	...	5,287	62
Gujar	2 May	19 ,,	1	1	3,368	3,353	40	6,761	49
Ziārat	4 ,,	11 June	1	1	1,257	1,353	106	2,716	66
Ashreth... ...	5 ,,	...	1	1	2,534	2,301	68	4,903	36
Kila Drosh ...	9 ,,	...	1	1	3,453	3,597	198	7,248	54
Gairat	14 ,,	1 July	1	1	629	684	...	1,313	28
Chitral	18 ,,	...	1	1	1,882	1,900	...	3,782	30
Darora	19 July	21 Sept.	1	1	949	1,136	8	2,093	33
Warai	20 ,,	22 ,,	1	1	1,010	878	26	1,914	30
Robat	19 ,,	23 ,,	2	3	2,033	1,953	7,432	11,418	173
Laram	27 ,,	25 ,,	2	4	5,992	7,221	84	13,297	221
Berchanrai ...	18 Aug.	21 ,,	1	1	827	914	...	1,741	51
Total messages disposed of on system ...					93,276	96,991	121,064	311,331	...

Table II. gives details of all the offices, with the staff employed in each, and the number of messages disposed of.

The objects kept in view were to afford the utmost facility for the through work, to keep the traffic moving continuously, and at the same time to arrange the local times to suit convoy work. The sections chosen were as follows:—

No. 1 Section.—Naushera to Khar, with intermediate offices at Hoti Mardan, Jelala, Dargai, and Malakand.

No. 2 Section.—Khar to Mundah, with intermediate offices at Chakdara, Serai, and Panjkora.

No. 3 Section.—Mundah to Dir, with intermediate offices at Kanbat, Janbatai, and Bandai.

No. 4 Section.—Dir to Chitral, with offices at Gujar, Ziārat, Ashreth, Kila Drosh, and Giarat.

While the headquarters were at Mirga, near Gujar, they worked Dir on a separate line. The work on No. 4 section was never very heavy. The sectional offices Khar, Mundah, and Dir kept open night and day. The intermediate offices worked from 6 to 7 in the morning, 12 to 1 at mid-day, 4 to 5 in the evening, and then opened at 9 p.m. to clear. These working hours were chosen to suit convoy work. They only worked with stations on either side of them, and with the sectional offices; that is, no intermediate office worked with an intermediate office on another section. Precedence was always given to messages regarding movements of convoys.

Press work was fairly heavy in April, in which month 255 messages, averaging 75 words each, were sent. In May 166 messages, averaging 97 words each, were sent. After May the Press work diminished greatly. Between all stations where it was possible heliographic communication was established, and this relieved the pressure on the wires to some extent.

It is curious to note how, even in the least important offices, there was fairly heavy and steady traffic. When the very small population of each post is considered—such, for instance, as half a dozen officers and a couple of hundred men—a daily traffic of 30 or 40 messages a day is high. It is very evident that the telegraph was thoroughly depended upon and fully used.

The conditions under which the work was done deserve mention. The offices were small tents measuring about 10 feet by 8 feet.

In the larger offices, such as Mundah, two were placed end to end. A rough thatch was fixed outside, but, as can be imagined, the protection from wind, dust, heat, and rain was but partial. There were incessant storms, accompanied by high winds and heavy rain. During one of these the office at Malakand was completely wrecked. Besides the actual receipt and transmission of messages, they all had to be checked, sorted, and bundled for check office scrutiny, and the rules were as strict as in an office on the general system. Notably at Mundah, and occasionally at other offices, the staff were exposed to "sniping," as already mentioned. The Mundah office was repeatedly fired at, and several bullet-holes in the tent showed that there were some very narrow escapes. Luckily, no one was hit, but it can be imagined that the whizz and rip of bullets through the tent is no pleasurable sensation. The staff, however, worked coolly and steadily through it all, and deserve very high praise for their conduct.

In Table III. is given a detailed account of the interruptions to communication.

Table III.—Summary of Interruptions.

Month.	Storms.		Enemy.		Transport Animals.		Faults in Offices.		Miscellaneous.		TOTAL.		Average Duration. Hours.	Remarks.
	No.	Hrs.	No.	Hrs.	No.	Hrs.	No.	Hrs.	No.	Hrs.	No.	Hrs.		
Apl.	1	13	...	...	11	36	...	...	...	...	12	49	4·1	Faults under "Miscellaneous" were imperfect communication and contacts, which did not cause total interruption.
May	2	48	20	155	6	34	...	...	4	17	32	234	7·3	
June	4	25	9	62	1	2	...	...	2	9	16	98	6·1	
July	2	11	11	96	...	...	1	2	1	5	15	114	7·6	
Aug.	...	...	4	36	1	2	...	...	7	32	12	70	5·8	
Sept.	1	9	2	22	1	14	...	...	...	...	4	45	11·2	
	10	86	46	371	20	88	1	2	14	63	91	610	6·7	

There were altogether 91 interruptions, aggregating 610 hours, and averaging in duration 6·7 hours each. This long duration was due almost entirely to interruptions caused by storms and by the enemy, in which considerable damage was done. Of the 91 interruptions, 56, lasting 457 hours, were due to these two causes. The majority occurred either in the

evening or during the night, and consequently nothing could be done till morning. 38 interruptions occurred in the daytime—that is, between 6 a.m. and 6 p.m.—and their average duration was 4·5 hours; whereas the duration of the 53 that occurred at night was 8·5 hours. The average distance to the fault from the nearest office was 6 miles, and the repairing party did not, as a rule, start till an hour after interruption was observed. During the day, therefore, the repairing party travelled 6 miles and repaired the damage, which was sometimes very considerable, in three and a half hours. During April there were constant interruptions caused by transport animals straying about. A camel always considers a telegraph post as something put up for him to scratch himself against. Naturally, 40-lb. posts were not calculated to stand this treatment, and broken posts were common. The camel-drivers were, however, speedily given to understand that they were responsible that their camels did not use the telegraph posts for scratching purposes. Once they realised the unpleasant personal consequences that followed disregard of these orders, interruptions from this cause practically ceased. Next month, however, a far more serious succession of interruptions were caused by the enemy, who night after night cut the wire, pulled down posts, and carried away lengths of wire. The greater number of instances occurred in the Jandol Valley, and the serious effect it had on our traffic may be imagined from the fact that between the 9th and 31st May—21 days—there were 151 hours', or 6¼ days', total interruption due to wire-cutting alone. Altogether the enemy carried away or destroyed 2½ miles of wire and 38 posts. Speculation was rife as to what they did with the material. At Mundah they were supposed to have made a gun out of a post wound with wire. There was also a legend to the effect that they erected a small line in one of their villages on the advice of one of their mullahs (or priests), who was greatly discredited when it was found the wire did not speak of itself!

Storms of great violence visited the line and caused 10 interruptions, aggregating 16 hours. In eight of these interruptions from one to six posts were smashed at a time, and in only one was the wire not broken.

Telephonic camp connections were put up in one or two of the big camps, and were found useful. Alarms for rifle thieves were also set up at Mundah, but their usefulness was not thoroughly established, as the trial was not sufficiently lengthy. In one camp movable connections were supplied for the outlying pickets. An indicator and bell were put up in the quarter guard and lines run thence to the enclosure of the fort. Each picket had about half a mile of cable on a drum, with an ordinary signalling key on it. The cable was unrolled as the picket went out. When they reached their position the sergeant in charge made contact once, ringing the bell in the quarter guard—the indicator showing which picket was signalling. In case of alarm they could signal according to a simple code of bell strokes. There is no doubt there is ample scope for such applications of electricity in frontier warfare, though at present they are only in the experimental stage.

This account of the work done with the Chitral Relief Force may fitly close with an extract from the Commander-in-Chief's despatch to the Government, which gives the following generous acknowledgment of the work done by the Department:—"In all "the previous despatches that His Excellency has written to the "Government of India on former campaigns, it has been an "agreeable duty to him to dwell upon the admirable organisation "of, and the excellent services rendered by, the Telegraph "Department. This expedition gives him yet another oppor- "tunity of commending the enterprise with which the telegraph "line was so rapidly carried forward with the advance, in the face "of all difficulties. . . . ."

ABSTRACTS.

R. APPLEYARD—INFLUENCE OF TEMPERATURE ON THE RESISTANCE AND INDUCTIVE CAPACITY OF DIELECTRICS.

(Philosophical Magazine, August, 1896, *p.* 148.)

The dielectrics experimented upon by the author were mica and paraffined paper in the form of condensers. The resistances were measured by the "direct "deflection" method, the testing voltage being 450 volts, and the galvanometer reading for each measurement taken after the testing current had been applied for one minute; other details of the tests employed are given in the paper. The temperature of the dielectrics was varied by enclosing the condensers in water-tight cases and immersing the cases in a water bath, the temperature within the dielectric of the condensers being taken by means of a platinum direct-reading thermometer, as described in *Philosophical Magazine*, January, 1896.

The results obtained are given in the following table:—

Temp. C.°	Paraffin Paper. Mean Values of Two Condensers.			Mica. Mean Values of Eight Condensers.		
	Capacity in Mfds.	Resistance. Megohms pro Mfd.	Elect. p.c. between 1 m. and 2 m.	Capacity in Mfds.	Resistance. Megohms pro Mfd.	Elect. p.c. between 1 m. and 2 m.
0·4	0·98	17,740	33	0·5	31,286	40
6·8	,,	11,510	30	,,	28,520	46
12·5	,,	7,216	28	,,	28,427	47
18·7	0·99	4,196	24	,,	—	—
19·7	0·97	3,825	25	,,	25,415	37
20·1	0·98	3,622	25	,,	22,000	42
22·6	,,	2,961	24	,,	22,327	44
24·4	,,	2,436	25	,,	—	—
26·9	,,	1,947	25	,,	16,272	43
29·0	0·97	1,659	26	,,	16,930	36
32·0	,,	1,231	26	,,	17,010	43
34·6	0·98	1,056	27	,,	18,457	30
37·8	0·96	792	28	,,	15,270	41
41·9	0·95	611	32	,,	10,340	33
43·3	,,	551	32	,,	10,521	38

From the above it will be noted that with paraffin paper condensers the capacity varies irregularly with the temperature, and that it *diminishes* as the resistance diminishes; this latter property being somewhat noteworthy, since the reverse is generally the case with india-rubber and gutta-percha.

Temperature Coefficients.—Assuming that the resistance, R_τ, of a dielectric at any temperature τ is represented by an equation of the form

$$R_\tau = R\,a^\tau,$$

and that, similarly, at some other temperature θ

$$R_\theta = R\,a^\theta,$$

so that

$$R_\tau = R_\theta \, . \, a^{\tau - \theta};$$

or

$$\log R_\tau = \log R_\theta + (\tau - \theta) \log a \quad \ldots \quad \ldots \quad (1)$$

From this equation, taking the 15 observations for paraffined paper, two at a time, in alternate order, and putting them successively as R_τ and R_θ in (1), we find as a mean value,

$$\log a = \bar{1}\cdot96344 \quad \ldots \quad \ldots \quad \ldots \quad (2)$$

The temperature θ may be given some standard value—say 20° C.—and from a curve drawn from the 15 observed values of resistance and temperature the corresponding resistance, R_{20}, may be obtained. The resistance at 20° C., found in this way, was, for paraffin paper,

$$R_{20} = 3{,}670 \text{ megohms};$$

equation (1) in this case becomes

$$\log R_\tau = 3\cdot56467 + (\tau - 20)(\bar{1}\cdot96344) \quad \ldots \quad \ldots \quad (3)$$

from which may be deduced the resistance corresponding to any temperature τ. It will be found that results calculated from (3) agree very closely with the observed values. In an appendix to the paper the author gives the reasoning on which the above formula is based.

The author also investigated the variation of the resistance of paraffin wax during change of state, *i.e.*, during fusion and solidification.

Heating.—Starting at 20° C. below the melting point, the resistance rapidly diminishes till actual melting begins; there is then a definite fall to approximately one-third of the resistance just before melting. If heat is still applied, the resistance remains constant until fusion is complete, when it again begins to diminish steadily. There was apparently no "electrification" while the wax was in the melted state.

The *spark-resisting power* of the melted wax was about one-third that of the solid material; in the particular case the insulation broke down at 1,200 steady volts, and was self-healing, similarly to an oil.

A converse process took place on cooling.

A. CAMPBELL—ON NEW INSTRUMENTS FOR THE DIRECT MEASUREMENT OF THE FREQUENCY OF ALTERNATING OR PULSATING ELECTRIC CURRENTS.

(*Philosophical Magazine, August*, 1896, *p.* 159.)

The author measures the frequency by setting a stretched wire, or a spring fixed at one end and free at the other, into vibration by placing it in a magnetic field produced by the alternating or pulsating current whose frequency is to be measured, and then adjusting the tension of the said wire or the free length of the

said spring until the point of maximum resonance is obtained. The wire is stretched in the one form of the instrument, and the spring shortened in the other form, by any suitable means, and the distance through which it is moved being measured by means of a rack which rotates a pinion carrying a pointer and causes the pointer to move over a scale graduated, say, in periods per second. In this manner, by varying the tension of the wire or the free length of the spring until the point of maximum resonance is found, the frequency can be read off directly on the graduated scale. The accuracy of reading is within from 0·2 to 0·3 per cent. The point of maximum resonance may be determined by fixing an adjustable piece near the vibrator, against which it jars when the resonance is sufficient; this device may also be combined with an electric circuit so as to ring a bell when the required position is found. In the stretched wire form of the instrument one end of the wire is attached to a suitable spring, and the other to the indicating and stretching devices; the other form of the instrument is, however, the more practical.

F. W. BURSTALL—ON THE USE OF BARE WIRE FOR RESISTANCE COILS.

(*Philosophical Magazine, September*, 1896, *p.* 209.)

The author has constructed resistance boxes in which the resistances consist of bare platinum-silver wire immersed in a pure heavy hydrocarbon oil. The principal advantages obtained by this form of construction are as follows, viz.:—The temperature of the resistance wire can be very easily ascertained; the heating produced by the testing current is much less than with covered wire; and, finally—which is perhaps the most important—the wire can be annealed in a most perfect manner by passing a sufficiently large current to heat it to a red heat for a few seconds: it having been found, by Dr. Lindeck and others, that well-annealed coils are much less liable to change than coils which have not been so treated.

As an example the construction of a Wheatstone's bridge is described. The wire of the 1-ohm coils—dia. = 0·63 mm.—was wound in the form of a spiral, which was screwed into holes pierced in a mica plate, this plate being screwed top and bottom to a brass bar attached to the ebonite top. The 10- to 1,000-ohm coils were wound on frames consisting of two or three brass crosses mounted on a central brass rod, these crosses serving to support serrated strips of mica; thus forming a four-sided reel, in the serrations of which the resistance wire is bifilarly wound. The containing box is lined with copper for the reception of the oil.

In constructing standard resistance coils, the mica strips are sometimes stiffened by slipping them into a brass back like the back of an ordinary tenon saw, which quite prevents any tendency to bend. The temperature is measured by means of a thermometer placed in a pierced tube which lies inside the coil. The author prefers the dial form of bridge, in which the dial blocks are connected to the zero socket of the preceding dial by heavy flexible leads (5 mm. dia., composed of copper wires 0·2 mm. dia.) and conical plugs fitting into conical sockets, as first constructed by Mr. R. W. Paul.

G. S. MEYER—ON THE INFLUENCE OF TENSIONAL AND COMPRESSIVE STRESSES ON THE THERMO-ELECTRIC AND MAGNETIC PROPERTIES OF THE METALS.

(*Wiedemann's Annalen, Vol.* 59, *No.* 9, *p.* 134.)

The author, as regards magnetic properties, discovered that the "Villari "point," in very weak magnetic fields, may also be observed with cobalt, in addition to iron and nickel.

The thermo-electric properties of the metals experimented upon (iron, steel, nickel, cobalt, copper, silver, brass, aluminium, gold, platinum, cadmium) may be described as follows:—

1. In non-magnetic metals, the electro-motive force produced by extension may be stated to be proportional to the tension, as a first approximation. Hysteresis is not perceptibly present.

2. In the experiments on the magnetic metals, attention had to be continually paid to the alteration in their magnetic condition which is simultaneously produced by the extension, since its influence may be of equal or even greater effect than that of the load. It appears to the author that the neglect of this circumstance, even if it be not the sole reason, is directly responsible for there being so many contradictions in the results of earlier observers as regards the magnetic metals.

3. With soft iron, the influence of the extension cannot be determined by itself, since it is always accompanied by alterations of magnetisation which probably mask the simple action of the tension.

4. With nickel and cobalt, extension produces an electro-motive force which is in the same direction as that due to longitudinal magnetisation. Since, however, tensional stresses at the same time cause a decrease of the magnetisation, the electro-motive force produced is the difference between the electro-motive force due to the extension alone and that due to the decrease in the magnetisation. With stronger magnetisations the latter can be made greater than the former.

5. The very slight alterations of the magnetisation in nickel and cobalt at the "Villari point" do not affect the electro-motive force sufficiently to produce a point of reversal in the thermo-electric curve.

6. The first application of the load with all metals influences the electro-motive force more than the succeeding ones.

W. JAEGER and R. WACHSMUTH—THE CADMIUM STANDARD CELL.

(*Wiedemann's Annalen, Vol.* 59, *No.* 11, *p.* 575.)

The authors investigated the cadmium standard cell proposed some time ago by Mr. H. Weston, of Newark, and which is practically independent of temperature. This cell corresponds exactly to the Clark cell, except that the zinc is replaced by cadmium.

The experiments related to—

1. The determination of the relation between the electro-motive force of the cadmium cell and that of the Clark cell;

2. The extent to which the cadmium cell is dependent on temperature;
3. The possibility of easy reproduction of the cell, and the influence of impurities;
4. The constancy during long periods of time.

The experiments showed that the alteration of electro-motive force of this cell amounts to only 4-1,000ths per cent. per 1° C. variation in the temperature of the room (the Clark cell about 1-10th per cent.). As regards constancy and facility of reproduction, it is not behind the Clark cell; its electro-motive force is near 1 volt.

1. *Electro-motive Force of the Cadmium Cell.*—The E.M.F. of the cadmium cell was determined by comparing it with that of the Clark cell at the temperature of the room (partly also at 0°) by means of a Feussner compensating apparatus, the resistance of which was previously measured. The Clark cells were made by Herr Kahle, and were of the Rayleigh H form.

In the comparisons as many of the cells were put in series as possible, and thus, for example, the nearly equal voltage of seven cadmium cells was compared with that of five Clark cells. The latter stood in petroleum baths the temperature of which was determined by a carefully tested thermometer, and observations were made both as the temperature of the bath was rising and when falling, so as to avoid errors due to the temperature of the cell remaining behind that of the bath. The cadmium cells also stood partly in petroleum, partly in air.

The mean of the observations gave, to an accuracy of 1 in 10,000, the ratio,

$$\frac{\text{Clark, } 15^\circ}{\text{Cadmium, } 20^\circ} = 1{\cdot}4063.$$

Taking the value 1·433 int. volt for the E.M.F. of the Clark cell employed at 15° C., the E.M.F. of the cadmium cell at 20° C. is 1·019 int. volts.

2. *Form and Composition of the Cell.*—The cell was made up according to the scheme,

$$Cd - Cd\,SO_4 - Hg\,SO_4 - Hg.$$

As regards the glass containing vessel, the H form due to Lord Rayleigh, with platinum electrodes fused in, is the most convenient, the electrodes being electrolytically amalgamated. Instead of pure cadmium, an amalgam of 1 part by weight to 6 parts of mercury was employed, which is fluid at 100°, and perfectly solid at ordinary temperatures (fusing point, about 60°). The mercurous sulphate ($Hg_2\,SO_4$) was rubbed to a stiff paste with crystals and a concentrated solution of cadmium sulphate together with mercury. From the different methods of employing the cadmium sulphate and the mercury resulted the following types of cell, of which Type III. was the one most frequently employed as being the most convenient and reliable.

Type I. has an amalgamated platinum spiral as the positive pole. Over the cadmium amalgam (negative pole) is a layer of cadmium sulphate crystals; the remaining part of the element is filled with the paste. Each limb is closed by a layer of paraffin on which lies a thin piece of cork; the cell is finally sealed with good sealing wax. In this condition the cell is portable, and can be entirely immersed in petroleum baths without the petroleum penetrating. The paste should be made fairly stiff, even though the resistance is somewhat increased thereby, &c.

order to ensure that no mercurous sulphate shall penetrate through the layer of cadmium sulphate crystals to the amalgam, since if this be allowed to occur the E.M.F. is altered irregularly.

Type II. differs from I. in that the positive pole is formed of mercury instead of amalgamated platinum.

Type III.—The paste is only placed over the mercury of the positive pole. On the negative pole (1 Cd : 6 Hg) is laid a layer of cadmium sulphate crystals. The remaining part of the cell is filled with a concentrated solution of cadmium sulphate. (A diagrammatic sectional elevation of this cell is given with the original paper.)

Temperature Coefficient.—The temperature coefficient of the E.M.F. was determined with cells made up with Kahlbaum's chemicals, which were not further purified. The cadmium sulphate showed no acid reaction with Congo red; the mercurous sulphate was free from acid and basic salt; the chemical examination of the different materials showed only traces of impurities. The six cells tested did not vary from one another more than 1×10^{-5} volts. The temperature coefficient was determined by immersing the cells in deep brass vessels filled with petroleum, the bath being brought to known, very constant temperatures either with ice or by large water baths.

The results of the observations at different temperatures are embodied in the formula,

$$E_t = E_{20} - 3{\cdot}8 \times 10^{-5}(t - 20) - 0{\cdot}065 \times 10^{-5}(t - 20)^2,$$

wherein E_{20} is to be taken as 1·019 volts.*

At present this formula can only be taken to be true between the limits 5° and 25°. It is noticeable that the cadmium element soon returns to its normal value after considerable variations of temperature, for example, between 0° and 26°.

The temperature coefficient of the Clark element at ordinary temperatures is consequently about 20 times greater than that of the cadmium cell.

Facility of Reproduction and Influence of Impurities.—In making up the cells with chemicals obtained from different manufacturers, the greatest variations from using impure chemicals only amounted to some ten-thousandths of a volt. Considering first the

Cadmium Amalgam.—In order to be quite sure, the cadmium should be that obtained electrolytically from cadmium sulphate solution. The worst impurity to be feared is zinc, which gives a too high value for the electro-motive force. Two per cent. of zinc added to a cadmium amalgam gave an error of $+ 39 \times 10^{-5}$ volt. The cadmium of commerce, however, only contains traces of zinc. As regards the composition of the amalgam, about 1 per cent. more cadmium in an amalgam than the normal gave an increase of 0·001 volt in the E.M.F.

Cadmium Sulphate.—An effective saturated solution of cadmium sulphate ($3\,CdSO_4 + 8\,H_2O$) can only be obtained by long standing and shaking with the pulverised salt, since only little more can be dissolved on heating. If this precaution be not observed, concordant results will not be obtained, since the E.M.F. is

* According to Kahle, the corresponding formula for the Clark cell between 10° and 30° is $E'_t = E'_{15} - 116 \times 10^{-5}(t - 15) - 1 \times 10^{-5}(t - 15)^2$

greater with dilute solutions than with concentrated; however, by adding pulverised cadmium sulphate the correct value can be obtained.

The calcium sulphate of commerce is of great purity, and contains only traces of other salts; it is, however, not always neutral, as tested with Congo red. To neutralise, if acid, it is digested with cadmium hydrate (obtained by precipitation from $Cd\,S\,O_4$ by sodium hydrate and repeated washing), filtered, and evaporated in a current of dry air until a considerable quantity of crystals separate. The solution so obtained should be treated with mercurous sulphate—warm—which is thereby coloured grey, due to the formation of mercurous oxide. The filtered solution will then have no perceptible action on the paste. The cadmium sulphate of good cells was rendered impure by adding $Zn\,S\,O_4$, $Fe\,S\,O_4$, $Mg\,S\,O_4$, and free acids, in the form of concentrated solutions, and uniformly distributed by stirring. The E.M.F. was only altered thereby to the extent of a few ten-thousandths of a volt, even for large quantities of foreign salts; therefore the traces of impurities which the cadmium sulphate of commerce contains can be disregarded. The cell treated with $H_2\,S\,O_4$ was at first stronger than the normal, but after some time it came within one ten-thousandth.

Mercurous Sulphate.—Even if the mercurous sulphate ($Hg_2\,S\,O_4$) be free from foreign metallic compounds, it may be impure by reason of the presence of free acid, or mercuric sulphate ($Hg\,S\,O_4$), or by basic compounds of both salts. As is known, a faint yellow coloration of the mercurous sulphate serves as a criterion that it no longer contains free acid. If the salt appear pure white, it should be washed with distilled water until a faint yellow coloration appears. This yellow coloration is attributable to the formation of the basic salt of the mercuric compound (turpeth mineral). This yellow coloration only takes place, on washing, if small quantities of mercuric salts are present; and it may happen that, in spite of repeated washing with distilled water, the mercurous salt remains pure white. Any free acid which is then not removed, and which can be recognised by its turning Congo red paper blue when dipped into it, will, however, be rendered innocuous, similarly to the mercuric salt, by the method of making the paste, in which metallic mercury in an extremely finely divided condition is present.

Cells were tried in which the mercurous sulphate was replaced by calomel, which can be obtained very pure in commerce. These cells have consequently the form,

$$Cd - Cd\,Cl_2 - Hg_2\,Cl_2 - Hg.$$

The temperature coefficient of these cells is, however, considerably greater. Their E.M.F. is about $\frac{2}{3}$ volt.

Constancy and Portability.—As regards constancy, of 33 cells only one varied more than one ten-thousandth of a volt from the mean at the expiry of two years.

To test the portability of the cells, two of them were sent by post for a distance of 600 kilometres. The measurements made showed that the cells had not altered in travelling.

This cell is not liable to a defect sometimes possessed by the Clark cell, viz., the formation of a layer of gas between the zinc amalgam and the crystals of zinc sulphate; this gas considerably increasing the resistance, and sometimes even interrupting the circuit through the cell.

MM. BERTHELOT and VIELLE—RESEARCHES ON THE EXPLOSIVE PROPERTIES OF ACETYLENE.

(*Comptes Rendus, Vol.* 123, *No.* 14, *p.* 523.)

Acetylene is an endothermic compound, of which the decomposition into its elements liberates about the same quantity of heat as does the combustion of an equal volume of hydrogen to form steam. This characteristic was discovered by M. Berthelot; he exploded acetylene by means of fulminate of mercury by operating on a constant volume ("On the Explosive Force of Substances," vol. i., p. 109).

The following researches were carried out with the object of showing the precautions which are necessary for the practical employment of acetylene:—

1. *Influence of Pressure.*—Under atmospheric pressure, and at a constant pressure, acetylene does not propagate to any notable distance the decomposition provoked at a point. Neither a spark, nor the presence of a point of ignition, nor a fulminate cap, produce any action beyond the neighbourhood of the region submitted directly to heating or to compression (MM. Maquenne and Dixon, *Comptes Rendus*, vol. cxxi., 1895).

The action has, however, been found to be quite different when the condensation of the gas takes place, and for pressures above two atmospheres. The gas then manifests the ordinary characteristics of explosive mixtures. If its decomposition is excited by simple ignition at a point by means of a platinum or iron wire heated electrically, then this decomposition is propagated to the whole mass without any appreciable decrease.

2. *Decomposition of Acetylene Gas.*—The following table gives the pressures and duration of reactions, observed at the moment of ignition of acetylene produced by a hot wire placed within the gas, studied under different internal pressures:—

Number of Experiment.	Absolute Initial Pressure (Kg. per Sq. Cm).	Observed Pressure immediately after the Reaction.	Duration of the Reaction in Thousandths of a Second.	Ratios of Initial and Final Pressures.
	Kg.	Kg.	Thousandths.	
38	2·23	8·77	...	3·93
43	2·23	10·73	...	4·81
28	3.50	18·58	76·8	5·31
31	3·43	19·33	...	5·63
39	5·98	41·73	66·7	6·98
26	5·98	43·43	...	7·26
32	5·98	41·53	45·9	6·94
25	11·23	92·73	26·1	8·24
40	11·23	91·73	39·2	8·00
29	21·13	21·37	16·4	10·13
30	21·13	21·26	18·2	10·13

The last duration of time is far below that of the explosive wave in an oxyhydric

mixture. On opening the exploding chamber, it was found to be coated with carbon. The product of decomposition is pure hydrogen; which, on cooling, is found to have the same pressure as the initial pressure. The decomposition consequently takes place according to the formula, $C^2 H^2 = C^2 + H^2$. The temperature of decomposition at constant volume is, by calculation, about $t = 2,750°$. The pressure developed would be about 11 times greater than the initial pressure; which agrees fairly well with the results observed with initial pressures of 21 kilogrammes. The duration of decomposition of acetylene decreases rapidly as the pressure increases, not only on account of the lesser influence of drop in temperature, but also on account of the effect of condensation. The ratio between the initial and developed pressures is calculated according to the laws of perfect gases. But this ratio must rise above the preceding limit, when the initial pressure increases by virtue of the increasing compressibility of the gas; the latter causing the charging density to increase more rapidly than the pressure, when the gas reaches its point of liquification. Concurrently with the increase of pressure, does the rate of reaction increase, the tendency being to approach nearer and nearer to the relative limit of the liquid state. These general relations were deduced from M. Berthelot's researches (*Essai de Mecanique Chimique*, vol. ii., p. 94), and notably from his experiments on the formation of ethers. Liquid acetylene supplies a new confirmation.

Decomposition of Liquid Acetylene.—It has been found that the reaction is propagated equally well in liquid acetylene, even when operating by simple ignition by means of an incandescent metallic wire. In a steel bomb of 48·96 c.c. capacity, charged with 18 c.c. of liquid acetylene (weight estimated from the amount of carbon collected), the great pressure of 5,564 kilogrammes per square cm. was obtained.

This experiment leads one to attribute to acetylene an explosive force of 9,500, or close upon gun-cotton. The bomb contained a block of carbon, agglomerated by pressure, offering a brilliant and conchoidal fracture, and which, according to M. Moissan's analysis, does not contain any graphite.

The decomposition of liquid acetylene by simple ignition is relatively slow. Two phases are observed in the action, the one probably due to the decomposition of the gaseous portion, and the other to that of the liquid portion. The authors have remarked the same characteristics of discontinuity in connection with the decomposition of gaseous and liquid mixtures. From the above experiments, it results that whenever a gaseous or liquid mass of acetylene under pressure, and especially at constant volume, is submitted to an action capable of provoking its decomposition and of producing a corresponding local increase of temperature, this reaction will be capable of propagating itself throughout its mass. The following are the conditions under which the decomposition into elements can be produced:—

Effects of a Shock.—The experiments were carried out with a vessel of 1 litre capacity, filled in one case with compressed gas at 10 atmospheres, and in the other case with liquid acetylene at a charging density of 300 grammes to the litre.

1. Allowing this vessel to fall from a height of 6 metres on to a solid metal surface had no effect.

2. Crushing the vessel under a weight of 280 kilogrammes, falling from a

height of 6 metres, produced no explosion or inflammability in the case of gaseous acetylene compressed to 10 atmospheres. In the case of liquid acetylene the shock was followed by an explosion after a short interval. This phenomenon may be attributed, not to the pure acetylene, but to the combustion of the explosive mixture of acetylene and air, produced, no doubt, by the sparks formed at the moment of the rupture of the iron receptacle.

3. A forged iron bottle, charged with gaseous acetylene at a pressure of 10 atmospheres, withstood without explosion the shock due to a shot which perforated an outer casing and depressed the inner casing.

4. An iron bottle, filled with liquid acetylene, was so constructed that a fulminate cap could be introduced to the centre of the liquid. 1·5 grammes of fulminate of mercury produced a violent detonation, and the fragments of the bottle presented the characteristics observed in the employment of known explosives. These fragments are represented in illustrations.

5. *Calorific Effects.*—Several causes accounting for the local increase of temperature are mentioned by the author, occurring in industrial operations in the preparation or employment of acetylene.

(*a.*) It may result from the attack of calcium carbide in excess, by small quantities of water, in an enclosed apparatus. The local increase in temperature may then be sufficient to produce ignition and explode the whole mass. The increase of temperature, thus provoked, may, besides, develop successive effects—viz., first determine the formation of such compounds of acetylene as benzine, stryolene, &c. (see *Ann. de Ch. & Ph.*, 4th series, vol. xvii., p. 52, 1867). This reaction in itself produces heat, and under certain conditions the temperature may increase to the point where the decomposition of acetylene into its elements becomes total, and perhaps explosive.

(*b.*) Other causes of danger in industrial operations may result from sudden phenomena of compression during the charging of the gas-holders, as well as from the phenomena of adiabatic compression which accompany the rapid opening of a vessel containing acetylene; into a receiver or any vessel of weak capacity. Under these conditions an increase of temperature would take place, causing a local decomposition, capable of extending to the gaseous mass under compression and as far as the holder.

(*c.*) A rough shock due to some external cause, and capable of breaking a bottle, does not appear to directly cause the explosion of acetylene. But the friction of metallic fragments against one another, or against external objects, is capable of igniting the explosive mixture consisting of acetylene and air—a mixture which is formed consecutively to the rupture of the holder.

In conclusion, the authors do not consider that the above disadvantages are of a nature to compensate the advantages which this illuminant offers, or to limit its use. It is easy to take precautions against these risks—for instance, to prevent too rapid a flow of compressed gas through the holders, and further to absorb the heat produced by compression and internal reactions of the apparatus in order to prevent any appreciable rise of temperature.

E. VILLARI—ON THE PROPERTIES POSSESSED BY "x" RAYS AND ELECTRIC SPARKS OF DISCHARGING ELECTRIFIED CONDUCTORS IN GASES.

(*Comptes Rendus, Vol.* 123, *No.* 16, *p.* 598.)

When gases are traversed by the x rays, the former acquire the property of discharging electrified conductors. Recent researches by the author show that they rapidly acquire this property, and that they maintain it for a considerable time.

When a gas contained in a zinc receptacle having an outer aluminium coating is excited by the x rays, and the tube is pushed by means of a glass tube against an electroscope, the latter is observed to discharge. But, on the contrary, it is not discharged if the current of gas is not excited by the x rays.

This property of discharging conductors, gradually disappears when the gas passes through longer tubes, either of glass or of metal, whether insulated or not.

These experiments have been made with air, oxygen, coal gas, hydrogen, and a mixture of air and of ether vapours, or of sulphide of carbon.

These gases acquire the same property when passed through a glass tube receiving a series of sparks from an induction machine working in conjunction with a condenser. It was found that the length of spark beyond 4 and 5 cm. had no sensible effect on the phenomenon. The effect is, however, doubled when four sparks, instead of a single one, are produced in the tube. The effect decreases when no condenser is used.

When a condenser is employed the effect is not diminished when a spark passes outside the tube, but it is materially when a resistance is introduced in the induced circuit. The effect somehow increases with the rapidity of the gaseous current, and diminishes with the length of the tube which conducts the gas from the sparking tube to the electroscope. This property cannot be attributed to the heating produced by the sparks in the gas, since the gaseous column when strongly heated by means of a flame, but not acted upon by sparks, does not discharge the electroscope.

E. VILLARI—THE ACTION OF THE ELECTRIC DISCHARGE ON THE PROPERTY POSSESSED BY GASES OF DISCHARGING ELECTRIFIED BODIES.

(*Comptes Rendus, Vol.* 113, *No.* 16, *p.* 599.)

The author discovers that gases acquire the property of discharging electrified bodies, not only by the action of the x rays, but also when they are traversed by a series of vigorous electric sparks. Further researches show that the gases traversed by sparks appear to acquire a greater conductivity for heat. This property acquired by gases of discharging electrified bodies may perhaps be attributed to a kind of dissociation of the gaseous molecules. This supposition led the author to try the effect of the electric discharge on gases. A current of air or oxygen was directed against the electroscope by means of a glass ozoniser. The electroscope was not discharged. The same effect took place with a current of coal gas or hydrogen. The discharge, therefore, does not then impart to gases the property of

discharging electrified bodies, but, on the contrary, the discharge appears to stop this property, which the gases may have previously possessed.

A current of gas rendered active by x rays or sparks was directed against an electroscope after having passed through a glass ozoniser.

With an inactive ozoniser the electroscope was immediately discharged, but the contrary effect was observed when the ozoniser was set in action. These experiments were carried out with air, oxygen, and coal gas. It is known that the products of combustion of flames rapidly discharge conductors.

In a preceding note the author has shown that this property decreases somewhat when these products are cooled. If these products are caused to pass through an ozoniser in action, they completely lose their properties of discharging conductors, as do also gases excited by x rays or sparks.

A. BUGUET—ON THE RÖNTGEN PHENOMENON.

(Comptes Rendus, Vol. 123, No. 18, p. 689.)

The author carries out further investigations on the nature of the x rays behind a lead screen. It has previously been observed that, although the screen may be sufficiently thick to protect a sensitive plate placed at the back and in contact with it, yet when placed at some distance from it the presence of the rays is evidenced by a circular region surrounded by a halo. By placing such a disc at a few cm. from a tube which is 10 to 15 cm away from a sensitive plate, and giving a long enough exposure, it was found possible to produce an impression over the whole photographic surface.

A number of pins were placed perpendicularly to the surface: their projections were observed as white on a grey ground; all these projections being directed from the centre towards the periphery, and towards the halo previously observed.

This, then, contradicts the suggestions that the x rays are directed towards the edge of the screen to penetrate behind it; for, if this were the case, the projections of these pins would be directed from the periphery towards the centre of the halo.

Nor does the author admit that the lead disc may be considered as transparent under the present conditions; for blocks of different thickness, placed at different positions on the surface of this disc on the side nearest the Crookes tube, showed no impressions on the negative.

It would appear that the particular condition of the space on the free path of the x rays extends to the neighbouring regions which are masked by the screen. The new properties are transmitted with all their characteristics, particularly those which decide the direction of the projection of the pins—characteristics which decide the direction of the x rays.

This transmission of properties is, moreover, an important function of the distance, from which results the relative narrowness of the halo.

The explanation of the air molecules, rendered active by direct radiation and carrying these new properties behind the opaque screen, does not offer an explanation for the steadiness of the phenomenon.

In a further series of experiments, a plate of lead covered part of the base of a cylinder of paraffin 15 cm. high, resting on a sensitive plate and considerably overlapping it. It was therefore separated from the photographic plate by paraffin at one end and by an equal layer of air at the other end.

The same effects were obtained with about the same intensity; as well also in the case when the lateral surface of the paraffin cylinder was covered with a sheet of lead destined to absorb the radiations coming obliquely from the surrounding air.

P. JANET—ON A METHOD OF MEASURING THE TEMPERATURE OF INCANDESCENT LAMPS.

(*Comptes Rendus, Vol.* **123**, *No.* 18, *p.* 690.)

By means of the results obtained by M. Violle for the mean specific heat of carbon between the temperatures of 0 and about 1,000°, the temperature of an incandescent lamp filament under certain conditions can be obtained. The method consists in applying to the terminals of the lamp, a difference of potential, E, varying from zero; and for each value of E the temperature will have a value θ, and the resistance a value R; a curve, A, is then plotted having R for abscissæ and $\frac{E^2}{R}$ for ordinates—that is to say, the power lost by radiation at a temperature θ. Next, a lamp is taken working under normal conditions and at a time 0, the current is broken, and the variation of resistance of the cooling filament studied as a function of the time. A curve is then drawn having time for abscissæ and the resistance R as ordinate. By means of the curve A, it will be possible to construct another curve, C, having the time for abscissæ, and as ordinate the power radiated at each instant: the area of this curve will then give the total power lost by radiation, from the maximum temperature of the filament down to the ordinary temperature; and, dividing by the mechanical equivalent of heat, the corresponding quantity of heat is obtained. It will then suffice to weigh the filament, and M. Violle's formula (assuming the filament to be of pure carbon) will give its temperature.

This, then, constitutes a simple method for studying the two important questions of the variation of resistance of carbon with temperature, and the variation of radiation with temperature. Generalised, it shows that the study of the variation of the resistance of any body with temperature, and that of the specific heat of this body, are two allied questions. It suffices to have independently studied one, to be in a position to investigate the other by the above method.

EDOUARD BRANLY—ON THE PROPERTY OF DISCHARGING ELECTRIFIED BODIES PRODUCED IN GASES BY INC DESCENT BODIES AND BY ELECTRIC SPARKS.

(*Comptes Rendus, Vol.* 123, *No.* 17, *p.* **643.**)

In a note in *Comptes Rendus*, 4th April, 1892, the
the results given by M. Villari in his communication of 1

With regard to researches on a unipolar conductivity of gases, after having shown how the rate of discharge of the disc of an electroscope was affected by an incandescent platinum wire, he added that the loss of charge was also produced by cooling the heated gases surrounding the incandescent platinum wire and projecting them on the disc. The cooled gases from various flames produce the same effects, as also do the gases produced by the electric sparks from an induction machine or an induction coil. A current of steam, hydrogen, or air, strongly heated and directed against the disc, produces no loss of charge.

The author is consequently of opinion that the electric sparks do not possess the special property which M. Villari attributes to them.

The above experiments, with additions, were described in the *Bulletin des Seances de la Société Française de Physique* (p. 215 to 230, 1892).

PAUL GIRAULT—THE ELECTRIC TRACTION APPARATUS OF THE FIVES-LILLE CO.

(*L'Éclairage Électrique, Vol. 9, No. 48, p. 185.*)

The generators constructed for purposes of electric traction by the above company, are of the multipolar design, having cast-steel magnets, and designed to maintain an almost constant voltage at the terminals of the motors.

The author gives a description of the plant used for the town of Angers. The generators are over-compounded by 5 to 10 per cent., according to the requirements, the open-circuit voltage being 500 volts. An illustration is given of one of the generators, the output of which is 275 amperes, 500 volts to 550 volts, at 375 revolutions per minute. The armature has a slotted core, and is series drum-wound, with helical end connectors. The charcoal iron discs are paper insulated, and are mounted on a cast-iron spider.

The insulation between the bars is effected by means of micanite strips forming as many double sections as there are grooves. Special attention has been paid to the ventilation of these machines.

There are as many brush spindles as there are poles. The carbon brushes offer a minimum section of 15 sq. mm. per ampere. The magnet carcass is of mild cast steel, and has the following peculiarity:—The magnets are bored out larger than is actually required, and when the coils are placed in position a "polar ring" is then fitted into the above bore. At a point midway between consecutive poles the ring is made thinner, and is pierced with a number of holes, in order to diminish magnetic leakage at this place. The object of this device is to reduce the lead of the brushes at full load—a most necessary point with traction generators. The switch-board in the generating station allows of the machines being readily coupled in parallel, or of any machine being isolated from the others.

The working of over-compounded machines in parallel, necessitates the use of an equalising bar, to which all the ends of the compounding on the armature side are connected; thus obviating all risk of reversing the polarity of the machines. At the Angers station the three generators installed can be individually connected

to the two main distributing bars, the positive being connected to the trolley wire, and the negative to the rails. Each machine has its automatic cut-out; the spark on breaking taking place between carbon contacts.

The overhead trolley wire is either of high-conductivity copper or of bronze, 8 mm. diameter.

In order to minimise drop along the trolley wire, feeders are employed. The feeding points are considered as distributing centres, and the feeders are so calculated as to maintain a constant potential at different centres of distribution, with consideration as to the over-compounding of the generators. The rails are suitably bonded by means of copper bars fitted into holes in them. The rails are also connected at intervals to a copper wire 8 mm. diameter running parallel to the rails outside the track. The negative pole of the generators is connected to earth, in order to diminish electrolytic action.

The trolley wires are suspended at a height of 6·4 metres above the track, and are supported in the usual manner by cross wires fixed either to posts or to buildings, and a ratchet for obtaining the required stress. The cross wires employed by the above company usually consist of steel strands having an effective section of 22 sq. mm., and a breaking stress of 2,000 kilogrammes. The supporting posts are of wood, steel tube, or of trellis. When the cross wires are fixed to walls, precautions are taken to deaden vibration by the use of a rubber pad.

The motors are specially designed to be as sparkless as possible, as the brushes have to be permanently set at their neutral position. Carbon brushes are employed.

The Fives-Lille Company construct several forms of traction motors. An illustration and particulars are given of a 15-H.P. motor (this includes gearing), the input of which is 30 amperes 500 volts. The motor has four poles. The armature is ring-wound. The core is made up of charcoal iron plates $\frac{5}{10}$ mm. thick, mounted on a bronze spider. The core has 67 longitudinal slots, in which are placed as many coils. The wires at the end of the core, before being connected to the commutator, are fixed to the periphery of a disc covered with a band of micanite 3 mm. thick. The commutator is made of a special alloy, suitable for working with carbon brushes. The wires on the armature are completely surrounded by micanite. The field magnets are of extra mild cast steel, so cast as to form a shell completely enveloping the motor. Mineral oil is used for lubrication. Each of the field-magnet coils is divided into three sections, four similar coils being connected in series. With these three groups of coils, different combinations can be obtained by means of the Sprague device.

Helical gearing, running in an oil bath, is used; the ratio being 1/5. The construction of the motors is such that the armature can easily be removed for repairs. Curves are given showing the results of brake tests. The trolley pole consists of a tapering iron tube. The trolley wheel is lubricated with a paste made of plumbago and oil, this being retained in grooves cut in the surfaces of the moving parts. Plumbago is used for purposes of conductivity. In order to make the contact of the trolley wheel as sure as possible, a carbon brush of circular section presses at the lower part of the wheel into the groove. The brush is connected to the motor by an independent copper wire. The foot of the trolley consists of a

frame on which are mounted eight springs, the tension of which can be adjusted by means of screws. This iron foot is mounted on a wooden frame, which is separated from the car by india-rubber, in order to prevent vibration.

The apparatus on the car consists of a main fuse, main switch, a lightning arrestor, and a metallic rheostat for starting and breaking. There are also two regulating devices, one for each platform. The lighting circuit has a fuse and a switch. The main fuse is contained in a stabilit box, and is so designed that a new fuse can be readily fixed in position. The main switch allows of the motors being coupled either in series or parallel. The cars are allowed to run at a considerably greater velocity out of the town than they are in the town. The lightning arrestor consists of discs of copper separated from one another with discs of mica 3 mm. thick, and threaded on an ebonite bush. The upper disc is connected to the main conductor, and the lower disc to earth; a fuse being placed in the earth connection to break circuit in the event of an arc being maintained by a great atmospheric discharge. The Sprague device effects a series of combinations between the armature, the resistance, and the three groups of field coils, for either one or both motors. A diagram is given showing 10 such combinations. These variations are effected gradually, in order to prevent sparking, and the field coils are always short-circuited before being disconnected.

There is only one handle for both the regulating devices, and it cannot be removed until the regulator is at the position of rest.

E. L. BOUVIER—A TELEGRAPHIC CABLE ATTACKED BY THE TERMITES.

(*Comptes Rendus, Vol.* 123, *No.* 9, *p.* 429.)

The author was requested by "La Direction des Postes et des Telegraphes" to examine a section of a telegraphic cable from Haiphong, which had been attacked by some organism.

According to the information supplied, the period of destruction must have been particularly short.

The cable was laid in good condition in 1894; it showed signs of weakness in the first days of 1895; the fault increased, and the cable had to be replaced in the first half of 1896. The cable was therefore rendered useless in less than two years. This cable had been specially manufactured for the purpose for which it was required. Nearly the whole of its length was buried in cement. It consisted of three conductors, each made up of seven strands. These were covered over with alternate layers of G.P. and Chatterton. The three conductors were laid up together with three prepared cords which filled up the intervals. Round the above, a layer of prepared jute was then wound spirally, then two prepared cotton tapes wound in the opposite direction to act as a binding, and the whole surrounded by a lead covering.

The researches carried out at Hanoi threw no light on the organism which had caused this trouble. Until this time the termites (white ants), "tarets," and wood-lice had not attacked the G.P. of cables, nor even that of covered wires at

the postal installations. The soil at Haiphong is damp and somewhat salt, being only slightly above the sea level, and would appear better suited to marine organisms; but it was found that terrestrial organisms had caused the trouble.

An examination of the sample of cable, revealed a number of borings 2 to 3 mm. diameter, running from the ends to the middle of the sample, and then from the periphery towards the centre. Parts of insects found in these borings were recognised to be those of the termites. Each boring appeared to have been carried out by one insect.

The author does not know whether the termites, as some insects, are capable of boring through the lead sheathing, but he is of opinion that in the above case the insects have bored through from the ends, or from accidental holes in the lead sheathing. The method of preventing this is to fix metallic caps on the free ends of the cable: to make the lead covering as perfect as possible; to see that the cord, jute, and cotton envelope are dipped in a saturated solution of sulphate of copper. The latter method is neither expensive nor complicated, and may in itself prove sufficient to limit or entirely prevent the above trouble.

J. PERRIN—DISCHARGES BY MEANS OF RÖNTGEN RAYS: INFLUENCE OF TEMPERATURE AND PRESSURE.

(*Comptes Rendus, Vol.* 123, *No.* 21, *February, p.* 878.)

The author has previously shown (*Comptes Rendus*, vol. cxxiii., p. 351) that the Röntgen rays, when passing through a gas at rest, produce at each point equal quantities of positive and negative electricity—quantities which are capable of moving under the action of an electric field, and consequently of destroying the terminal charges of the tubes, wherein they are contained. The author also showed that it is possible to measure the quantity of neutral electricity thus dissociated by the rays: that it varies inversely as the distance from the source, and can therefore be considered as proportional at each point to the intensity of the radiant system.

Further researches carried out by the author, were made with the object of ascertaining how the variations of pressure and temperature influenced this dissociation. It was found that, with a constant temperature, and between the limits of pressure of 7 cm. and 116 cm. of mercury, the quantity of electricity delivered by the condenser is proportional to the pressure.

Hence, at each point, the specific mass of the gas is proportional to the pressure. From this it results that, at a constant temperature, and for the same gas, the quantity of electricity dissociated by unit mass is independent of the pressure. With regard to variations of temperature, it was found that these had no influence on the discharge of the condenser. This fact led the author to employ a zero method, which he has previously described, and which eliminates the influence of variations of intensity of the source. It was found that, at each point of a condenser subjected to a variable temperature, the specific mass is inversely proportional to the absolute temperature; therefore, as the discharge remains constant, the quantity of electricity dissociated by unit mass is necessarily proportional to the absolute

temperature. It is of interest to recall here that, according to the kinetic theory of gases, the amount of energy in a molecule is also independent of the pressure, and is proportional to the absolute temperature.

It may be concluded from the above results, that for each gas the number of dissociated molecules is proportional to the number of molecules which come in contact with one another, whatever their distance apart, and is also proportional to their mean energy.

H. BECQUEREL—ON THE DIFFERENT PROPERTIES OF URANIUM RAYS.

(*Comptes Rendus, Vol.* 123, *No.* 21, *p.* 855.)

The author showed several months ago, that uranium and its salts emit invisible radiations which traverse opaque bodies and possess the property of discharging electrified bodies at a distance. These radiations share the properties common to the x rays, but differ in the fact that they are reflected and refracted in the same way as light. Amongst the properties observed by the author whilst studying these rays, which he terms "uranium rays," there are two which he publishes—viz., the duration of emission, and their power of communicating to gases the property of discharging electrified bodies.

With regard to the duration of emission, the uranium salts, when kept in the dark, continue to emit their radiations after many weeks. Many phosphorescent and non-phosphorescent salts of uranium were experimented with. These salts were placed on a glass plate, and some of them protected from the air by a sealed glass jar. They were then placed in a double lead box, and so arranged that a photographic plate enclosed in a lead shutter could be slipped under the salts without opening the box. Some of the salts were placed in the box in March, and some in May. Negatives developed in November were nearly as intense as previous ones. It is therefore to be noted that the duration of emission of these rays, differs materially from the ordinary phenomena of phosphorescence, and it still remains to discover the source from which uranium borrows the energy which it emits with so much persistence.

With reference to the dissipation of the charge of electrified bodies, amongst other properties possessed by the x rays, Mr. J. J. Thomson has discovered that not only the direct action of these rays discharges an electrified body at a distance, but that, after having caused these rays to act on a mass of gas, it suffices to cause the gas to pass over the electrified body to discharge it. M. Villari has shown that electric sparks, but not the silent discharge, communicate the same property to different gases.

The author has investigated whether these uranium rays, which discharge electrified bodies at a distance, would not impart this property to different gases.

The current of gas (air or carbonic acid) was caused to pass through a tube containing wool to filter it of all dust, and after this through a second tube containing the uranium salt; the end of this tube opened out on the ball of an electroscope.

In the second series of experiments, the second glass tube was replaced by a cardboard box containing a disc of metallic uranium, the box having two holes, one of which allowed the gas to pass out on to the ball of an electroscope. Under these conditions, if the uranium is not placed in the box, the electroscope remains charged, even when the current of gas is passed upon it, so long as the gas is free from dust. When the current of gas is stopped, and the uranium is placed in the box, or a uranium salt is placed in the tube, the electroscope shows a loss of charge due to the direct action of the uranium rays. For example, in an experiment with metallic uranium, the rate of falling of the leaves (expressed in seconds of angle per second of time), which was 3 without uranium, became 16·7 with it. The current of air was then started, after having passed over the metallic uranium, and produced a considerable dissipation: the rate of fall of the gold leaves was 88·6. The double sulphate of "uranyle" and potassium, with similar currents af air, gave an average of 23·9, as compared to 71·9 with metallic uraninm. The ratio is therefore 3. The direct action of uranium rays emitted by these two substances on the electroscope in air, previously gave the ratio of 3·65. The ratio is therefore about the same in the two cases, the discrepancy being no doubt due to leakage of air through the cardboard box. This proportionality shows that the effect is not due to the action of particles, or of vapours from the metal or from the salt. This was further proved by wrapping the uranium disc in black paper. Experiments made with a current of carbonic acid gas yielded results of the same order, but the currents were very weak, and the difficulty of regulating their velocity prevented obtaining figures as directly comparable as the above. These results conclusively prove that gases which have been submitted to the action of uranium rays, possess the property of discharging electrified bodies.

A. LALA and A. FOURNIER.—INFLUENCE OF MAGNETISM ON THE ELECTRO-MOTIVE FORCES OF BATTERIES IN WHICH IRON FORMS ONE OF THE ELEMENTS.

(*Comptes Rendus, Vol.* 123, *No.* 20, *p.* 801.)

A thermo-electric couple consisting of a strip of copper was clamped tightly between the two armatures of an electro-magnet, in such a manner as to form a symmetrical arrangement. A reflecting galvanometer, placed in an adjacent room, was connected at one terminal with the copper electrode, the other terminal being connected to the iron armature and earth. On heating the couple, a displacement of about 6 cm. was noted. On exciting the electro-magnet, a displacement of 3 cm. was observed, accompanied by a drop in the electro-motive force, which did not alter on reversing the direction of the field.

This is an analagous result to that observed by M. Grimaldi, on a bismuth-copper thermo-couple. Notice was taken that the magnetic field did not produce any permanent deflection of the galvanometer. This, on the contrary, produced a very small displacement (1 mm., about), quickly disappearing, and in the opposite

direction to that of the observed phenomenon. The diminution of the electromotive force was therefore due to the action of the field on the couple.

With the same conditions of symmetry as the above, this experiment was repeated with a hydro-electric couple formed by a hollow block of paraffin 7 mm. to 8 mm. thick, of which the armatures of the electro-magnet formed the sides and one of the electrodes. This block contained distilled water, in which was placed, between the two iron faces and at a fraction of a millimetre from each of them, a strip of copper forming the second electrode.

This hydro-electric cell, gave a current slightly lower than that of the thermo-electric iron-copper couple. The observed phonomenon was of the same nature; and the diminution of electro-motive force during the presence of the field was about 1-20th of the normal electro-motive force of the cell.

This experiment, in contradiction to the results obtained by MM. E. L. Nichols and W. S. Franklin, confirms, by a different experimental method, those of MM. H. A. Rowland and L. Bell, Hurmuzescu, and the theoretical considerations of M. Janet and M. Duhem

CLASSIFIED LIST OF ARTICLES

RELATING TO

ELECTRICITY AND MAGNETISM

Appearing in some of the principal Technical Journals during the Months of JUNE, JULY, AUGUST, SEPTEMBER, OCTOBER, and NOVEMBER, 1896.

S. denotes a series of articles. I. denotes fully illustrated.

ELECTRIC LIGHT AND TRANSMISSION OF POWER.

Körting and Mathiesen—Experiments on the Jandus Arc Lamp.—*E. T. Z.*, No. 23, p. 347, 1896.

Anon.—A New Polyphase System.—*Ibid.*, p. 348 (I.).

F. Uppenborn—Notes on some Improvements in the Installation System of the firm of Hartmann & Braun.—*Ibid.*, No. 24, p. 364 (I.).

F. Pflaumer—Electric Installations in Damp and Marshy Countries.—*Ibid.*, p. 365 (I.).

Anon.—The Protection of Large Plants against Lightning.—*Ibid.*, No. 25, p. 375 (I.).

Anon.—The Utilisation of the Water Power of the Rhone.—*Ibid.*, No. 26, p. 391 (I.).

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